Training Programme on Energy Planning for South Asian Countries

Capacity Building in the Energy Sector

January 10-15, 1994
Rajputana Palace, Jaipur

Organised by
Tata Energy Research Institute
9 Jor Bagh, New Delhi

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Training Programme on Energy Planning for South Asian Countries
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	Session 1	Session 2	Session 3	Session 4	Session 5
Monday 10 January	Inaugural session	Introduction to capacity building in the energy sector - Dr R K Pachauri TERI	Energy-economy linkages - use of modelling approaches? - Dr R K Pachauri, TERI	International negotiations on Climate Change Developing countries perspectives and priorities - Dr P Ghosh TERI	Group Discussion Common Issues in energy planning for South Asian Countries - Dr R K Pachauri TERI (Chairperson)
Tuesday 11 January	Electricity system planning - models from developing countries - Mr Krishna Swarup, PFC	Issues in the hydrocarbons sector with special reference to oil imports and demand management - Mr Prabir Sengupta TERI	Energy demand in agriculture - Dr R C Maheshwari ICAR	Panel Discussion Role of private sector in commercial energy supply - Mr Krishna Swarup PFC (Chairperson) - Mr A M Sahni, Tata Electric Co Ltd	Sight-seeing
Wednesday 12 January	Rural energy scenario - Mr P Venkata Ramana, TERI	Urban transport planning and implications for energy demand - Dr Y P Anand Former Chairman Railway Board	Industrial energy conservation - Case studies - Mr P K Dadhich, TERI	A review of electricity pricing in developing countries - Dr Bhaskar Natarajan, TERI	Group Discussion Integrated energy planning
Thursday 13 January	Panel Discussion Integrated Energy Planning (based on group discussion) - Dr Y P Anand, Former Chairman, Railway Board (Chairperson) - Mr P Venkata Ramana, TERI - Dr Bhaskar Natarajan, TERI	Renewable energy policy and planning - Dr J Gururaja MNES	Renewable energy technologies - economics and potential - Mr P Venkata Ramana, TERI	Natural resource accounting - Ms Shubhra Bhatia, TERI	Panel Discussion Capacity building - A critical element of environment and natural resource management - Prof C K Varshney SES JNU (Chairperson) - Mr P Venkata Ramana TERI - Dr J Gururaja, MNES
Friday 14 January	Environmental considerations in project planning - Prof G K Kadekodi, IEG	Environmental effects of coal mining - A case study - Mr P V Sridharan TERI	Environmental impact assessment of large scale methods of power generation - Dr Damyant Luthra, TERI	Environmental implications of energy use in the transport sector - Dr Ajay Mathur, TERI	Indoor air pollution - Dr Veena Joshi TERI
Saturday 15 January	Technology upgradation in the energy sector - Dr Ajay Mathur, TERI	Panel Discussion Institutionalizing capacity building in energy planning - Dr V S Vyas, Institute of Development Studies (Chairperson) - Dr Veena Joshi TERI - Dr Ajay Mathur TERI	Valedictory Session (H E Dr Neville Kanakratne)		

Introduction to Capacity Building in the Energy Sector

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Training Programme
on Energy Planning
for South Asian Countries

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INTRODUCTION

This paper deals with various dimensions of the concept and measurement of full agreed incremental costs, which is the main fulcrum around which transfers of resources and technology are likely to take place for the mitigation of global environmental problems The paper commence by exploring the concepts related to the definition of full agreed incremental costs and by identifying specific costs and benefits related to projects in general and those relevant to the field of environmental protection in particular The theoretical and methodology issues involved in the definition of these costs and benefits are fairly complex and it is only through the development of an appropriate conceptual framework that the numbers can be expected to fall in place appropriately

Costs have to be seen at both the micro and macro levels and there are important linkages relating to these two sets of variables These are also relevant to the consideration of technology transfer issues and the transaction costs involved The Asian Energy Institute (AEI) has carried out collaborative research on the estimation of greenhouse gas emissions in specific countries of Asia and has attempted to identify a set of mitigation strategies and has estimated costs associated with them The results of this attempt, which is perhaps the first such research effort undertaken in the Asian region, are presented in the paper, not only because they are useful in providing a quantitative flavour to the issues involved but also because through this expose the various complexities and difficulties, both conceptual and data-related come out much clearer

The GEF as an institution young in terms of the years of its existence The expectations that the global community has from it and the tasks that it has already had to tackle have perhaps left several students of the field with questions in their minds on the relevance and efficacy of the GEF's structure If the GEF is to be the principal mechanism for the transfer of resources and technology in implementing the two Conventions signed at Rio, then its structure and functioning would not only have to be totally in tune with the challenges of the future, but must appear to be so for the majority of the Parties to the two conventions In this spirit, the paper also explores institutional and organisational issues related to the structure and functioning of GEF, drawing analogies from other global agreements that are in place to day

Finally, it is brought out in the paper that several of the measures that would have to be implemented for protecting the global environment in the future, particularly in the developing countries, would require the generation of indigenous capacity for undertaking efforts not implemented in the past.

The importance of capacity building and its direct effects on the cost and effectiveness of mitigation strategies has been brought out in the paper Also, certain conceptual issues have been explored and directions provided on how capacity building could take place effectively in the developing countries to ensure the success of GEF operations in various parts of the world It is also emphasized that approaches to capacity building would necessarily have to deviate substantially from efforts undertaken in the past which have suffered largely from mindsets and rigid attitudes based on a flow of know how and expertise only from North to South, with little development of capabilities at the local level in the Third World

Section I
DEFINITIONS

Under both the Biodiversity and Climate Change Conventions, the concept of "full agreed incremental costs" (FAIC) of an abatement/conservation strategy plays a vital role Both Conventions decree that developing countries are liable to take measures towards fulfilling their responsibilities only if the associated FAIC are met by developed countries This section provides a working definition of incremental costs It also develops a Linear Programming (LP) model to arrive at a concept of "minimal incremental costs" -- a notion of economic costs which policy makers could agree upon as the *least* that would be involved in such programs

The "costs" considered in this paper are economic, not financial Economists distinguish between these at three levles First, financial costs, as typically determined by an accountant, involve only actual financial expenses (on capital, labour, materials, taxes, depreciation) Economic costs, on the other hand, are "opportunity costs", i e, the benefits foregone by not utilizing a given resource in the best alternative use

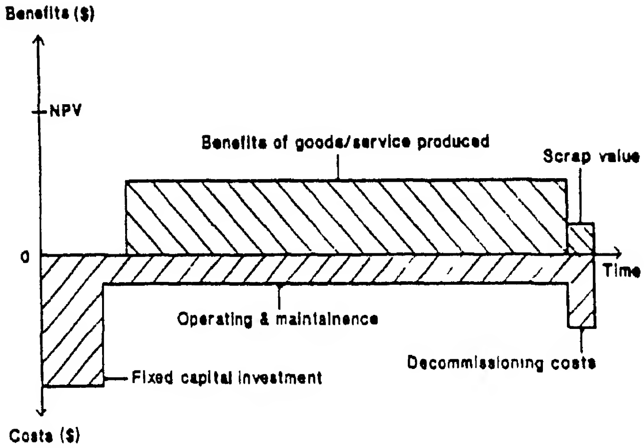
Further, economic costs exclude transfer payments such as taxes and subsidies, since these do not represent any direct claims on the resources of the economy They merely represent a transfer of control over the resources from one agent to another within the economy For example, when a firm pays taxes to the government these do not form a part of economic costs since all that occurs is a transfer of purchasing power from the firm to the government However, if the government were to use the funds so obtained to, say, construct a dam, then these expenditures would constitute economic costs

Third, economic costs correct for market failures -- for example by including externality costs, which are costs passed onto third parties not involved as producers or consumers of the good/service in question In the case of environmental externalities, it is assumed that these refer to local, not global impacts In other words, it is assumed that the national strategy either ensures that no global warming impacts are perceptible, or that all costs of adaptation or damage are met under other regulatory arrangements

Costs and benefits of a given project

Each project is associated with a stream of benefits and costs over time[1] However, these values are not strictly comparable since agents (individual, firm, society) typically have a (positive) time preference, i e , they prefer to reap benefits earlier and pay costs later Discounting reduces these values to a common denominator The discount rate used is the social (rather than the private) discount rate since we are considering the problem from the viewpoint of the policy analyst[2] The perspective is deterministic, i e , no uncertainty attaches to any element of costs or benefits associated with the known (set of) technologies Figure 1 depicts a typical project profile of costs and benefits Net economic benefits or net present value (NPV)[3] is computed as the sum of each year's benefits less costs, discounted by the discount factor That is

Fig 1: Typical profile of costs and benefits of a project



$$NPV = \sum_{t=0}^{T} \frac{B_t - C_t}{(1+S)^t} \qquad (1)$$

where

B_t Benefits at time t, C_t Costs at time t, S Social discount rate

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[1] Techniques for computation of the elements of economic costs (and benefits) are detailed in several standard texts on cost-benefit analysis, and will not be repeated

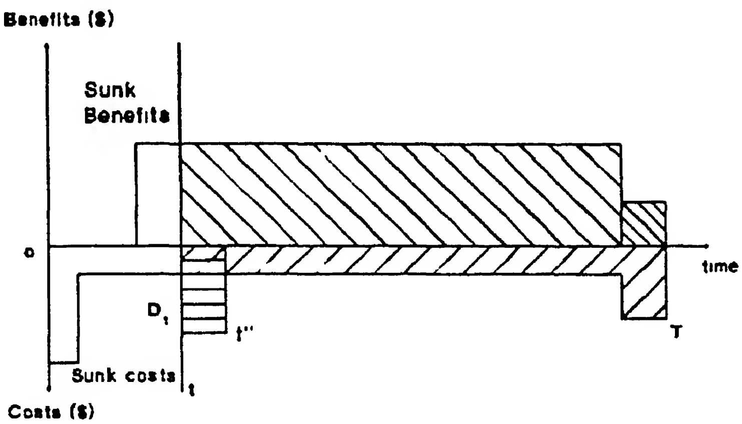
[2] Note that the social discount rate represents a societal choice, i e , the respective weights attached to identical benefits (costs) occurring at different times Techniques for computing social discount rates are also elaborated in the cost-benefit literature They aresome what controversial, but we do not go into these aspects in the present paper

[3] The NPV is the criteria of ranking alternative projects on the basis of the respective gains in economic efficiency that they yield

Costs and benefits of an "interrupted" project

An abatement program may involve the interruption of an existing plant before its "normal"[4] economic life is over, and its replacement by another plan7t embodying an environmentally benign technique Figure 2 depicts the costs and benefits of project interruption

Fig 2: Computing foregone costs & benefits of project interruption



The project involved here commenced at t = 0, and its lifetime (without interruption) would be till t = T However, it is interrupted at t = t' and decommissioned, over the period t = t' to t''

All "past" benefits and costs of the project (i e in the period t = 0 to t') are considered "sunk" The foregone costs and benefits are reckoned over the period t' to T The "net foregone benefits" (NFB) at t is the discounted value of all costs and benefits foregone by the interruption less the net costs of decommissioning where all streams are discounted to the point of decommissioning Mathematically

$$NFB^{t'} = \sum_{t=t'}^{t=T} \frac{(B_t - C_t)}{(1+S)^{(t-t')}} - \sum_{t=t'}^{t=t''} \frac{D_t}{(1+S)^{(t-t')}} \qquad (2)$$

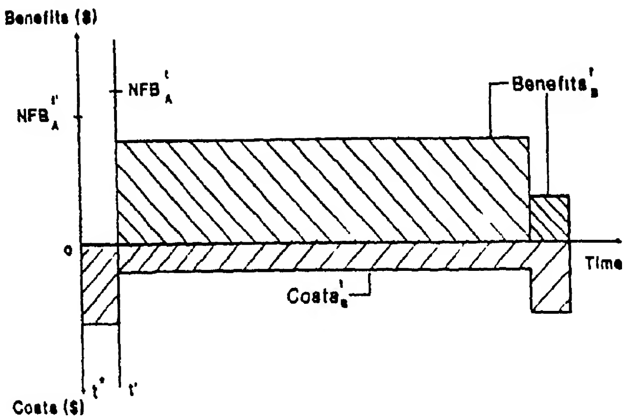
where D_t is the net costs of decommissioning (i e , inclusive of any scrap value)

Definition of "minimal incremental cost of an abatement option"

We now employ the concepts developed above to define the "minimal incremental costs" (MIC) of an abatement option involving the interruption of an existing plant and its replacement by an environmentally benign technique The situation is depicted in Figure 3 (where the phasing of costs and benefits of the replacement plant are illustrated not those of the existing plant)

[4] "Normal' in the sense of in the absence of a GHGs abatement program

Fig 3: Costs & benefits of a replacement project



The existing plant is termed A, and the replacement plant B Both plants are assumed in this definition to yield the same level of service (e g, MW of electricity) The NFB of the existing project A, which is interrupted at t = t' when the replacement project B goes on stream so that there is no interruption of service is NFB_A^t computed as explained in the previous sub-section Discounting this value to t^*, the point of time when investments in the replacement project B commence, we arrive at the NFB of project A at time t^* as

$$NFB_A^{t^*} = \frac{NFB_A^{t'}}{(1+S)^{(t'-t^*)}} \qquad (3)$$

The NPV of project B at $t = t^*$ may be computed as described above (by using equation (1)) The "minimal incremental cost of switching from A to B at time t^*" is defined as the difference between the net foregone benefits of the existing project A and the net present value of the replacement project B, both reckoned at the time when investment in the replacement project commences That is

$$MIC_{AB}^{t^*} = [NFB_A^{t^*} - NPV_B^{t^*}] \qquad (4)$$

From project level to program minimal incremental costs

An abatement program under a national strategy to limit GHG emissions will involve a large number of options While one may work out the MICs of particular abatement options, an important policy question is how to choose a least cost set of abatement options over a planning period, given two types of constraints in each period First, the GHG emissions/intensities path specified under the national strategy Second, that capacity in each sector of the economy in the following period, which is known or determined exogenously in the current period

A detailed Linear Programming (LP) model is set out in the Appendix to both define, and determine, the minimal incremental costs of such a program. The policy objective is assumed to be the minimization of the total economic costs of adhering to the abatement path

at each planning period[5] This is in keeping with the provisions of the Conventions, that any abatement measures undertaken by the developing countries are contingent upon the transfer of finances (and technology) from the developed countries

The planning horizon is one period, since it is assumed that future capacities in each sector are known only up to one period in advance Additionally, the set of available techniques is fixed only for one period in the future The economy adheres to the specification of GHG emissions/intensities at the beginning and end of the period There is a discrete set of techniques, which may be embodied in current and future plans An abatement option consists of a switch from an existing plant to another employing an environmentally benign technique Such technique switches are, however, restricted to those in the same sector For example, an electric thermal power plant may be replaced by another electric power plant employing a more GHG benign technique, but not by say, an aluminium smelter

Apart from switches in technique involving the same levels of service, the economy may make fresh investments (retirements) in each technique, in keeping with its growth/economic structure objectives, detailed in the set of sectoral capacities at the next period

Minimal incremental costs are involved in each abatement technique, and there are net benefits (net foregone benefits) in each case of fresh investment (retirement) Expressed as costs (i e net benefits are negative costs), these are aggregated into the total costs of the abatement program[6] An LP model is then specified, minimizing these total costs, subject to the sectoral capacities (for the next period) and the environmental constraint stipulated in the national strategy

A numerical solution of this LP model may be obtained by standard algorithms (e g the Simplex or Karmarkar methods) The solution will furnish the "optimal" levels of technique, as well as the set of fresh investments (retirement) in each technique for each period These

[5] One may suppose as an alternative, that the policy objective could be to minimize the sum of the minimal incremental costs of individual options As a planning objective for DCs this is implausible because it would not ensure that the total costs of remaining on the specified abatement path, given the society's growth objectives, are also minimized

[6] Where negative costs (net benefits) are involved in a particular abatement option these are excluded from reckoning of total costs on the assumption that these options may be adopted anyway, i e , even in the absence of a national strategy

elements of the solution may be employed to determine the"minimal" incremental cost of the abatement program in each period.[7]

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7 "Minimal" in the sense that these are the incremental costs associated with the minimum of the total costs as determined by the LP Moreover, they are determined on the basis of the MIC associated with each switch from technique i to j

Section II
TRANSACTIONS COSTS, TECHNOLOGY TRANSFER & MACROECONOMIC IMPLICATIONS

The above formulation of program level minimal incremental costs of such a conservation strategy captures only its direct economic costs In particular, they omit the "transactions costs" of actual conservation programs as well as transfer payments Further, the program may spread over a significant part of the economy, and involve general equilibrium effects In computing incremental costs, a significant component is attributable to technology transfer arrangements, which are important negotiable issues between developing countries and the financial mechanism involved These aspects are discussed in this section

Transactions costs and transfers

Two kinds of occult "costs" may be involved in any conservation program First, there may be societal impacts whose remedies may involve either transfer payments or real opportunity costs, or both For example, coal miners may be thrown out of employment in a program of decarbonization of the energy supply sector The young and relatively better educated among them may be amenable to retraining for other occupations Expenditures on such retraining (and subsequent job search and relocation) are real resource costs The older set of miners may not be restrainable and thus be obliged to retire before normal superannuation This represents a premature scrapping of the human capital embodied in such workers, which may be valued as their remaining discounted stream of wages till superannuation under the "no conservation responsibility" growth path, and is also a real opportunity cost Transfers may also be involved in the form of severance gratuities as well as other welfare payments ("unemployment doles") which may continue over the long-term Real resource costs would also be involved in organizing the retraining/rehabilitation programs as well as the welfare/dole programs

From a policy perspective, transfer payments represent actual financial outlays, and may be at least as problematic as real opportunity costs, many of which (for example scrapping of human capital) may not be visited directly on the public budget, or may be only to a limited extent Real world policy making must contend with the fact that these transfer payments are an essential lubricant of any abatement program, and that governments may face unacceptable political costs in raising monies for these programs domestically, by either additional revenue generation or cutting other public expenditure Accordingly, for the purposes of devising funding schemes for conservation programs, such transfer payments would need to be fully funded Would such full funding lead to a "moral hazard" problem, i.e , knowing that an external agency would meet all payments, but would be unable to ascertain the actual political costs

sought to be countered by means of the transfers, governments may be particularly lavish in devising compensatory packages, hoping to transmute political costs to (partisan) political benefit? It is difficult to rule out this possibility, and for that reason, as a second best solution it may be appropriate to devise full funding of such transfers on a normative basis, the norms being fine tuned to each country and sector, rather than on a case-by-case-basis. Clearly, there would be an element of negotiation in devising such norms

Second, resource costs may also be involved in the planning, monitoring, and regulation of the abatement program Such costs would be incurred for capacity building at both human and institutional levels, as well as in the actual administration of such functions The question of capacity building is discussed at length elsewhere in this paper At this stage we need to note that both capacity building and administration costs must be considered as part of the conservation program costs, although they would be difficult to apportion among the individual projects comprising the overall program It is true, of course, that capacity building, in particular, may have significant positive externality effects on other fields of public activity For example, through exposure to sustainable development concepts and approaches policy makers may generally imbibe a culture of reliance on incentives based policy instruments as opposed to fiats, which may beneficially infuse policy actions not directly bearing on conservation choices However, it must be understood that in devising a capacity building program, little note is likely to be taken by policy makers and development agancies of such external effects, and the entire costs of capacity building must be considered as part of the overall conservation program

Technology transfer issues

A major element of the costs of strategies to mitigate climate change as a part of the multilateral regulation of the international environment are related to technology transfer Two broad classes of issues are involved

First, transfers of benign technology are essential if developing countries are to meet their differentiated responsibilities in abating environmental damage R&D for such technologies have largely been carried out in the industrial world, whose firms accordingly own the relevant IPRs Technology transfers need to occur from these technology owners to the relevant developing countries agents, and the important policy questions relate to the terms, depth of, and mode of such technology transfers In this paper, we are concerned with this class of technology transfer issues

Second, environmental protection and perhaps traditional knowledge will furnish important positive inputs or externalities to the process of technology creation and the issue

here is how to ensure that developing countries realize payments for such environmental services, including perhaps in the form of (a share of) property rights over the resulting technology This second category of technology transfer questions is not dealt with in this paper

Important questions for defining incremental costs of technology transfer relate to mode, and categories of transfers [8] We briefly review these aspects below

Categories of technology transfer

Technology transfer may be distinguished in terms of three alternative flows (Bell, 1990)

One, capital goods, services and design specifications may be transferred ("Flow A") to alter to advantage, the production capacity of the recipient However, no knowledge and/or information is transferred, which may enable the transferee to alter, adapt, or further develop the received technology

Two, knowledge and skills (or "know-how") may be transferred by various means (i e , "paper embodied technology" manuals, schedule, flow charts, etc or "people embodied technology" knowledge and skills through training) to enable the operation and maintenance of the new production facilities ("Flow B")

Three, the extent of knowledge and expertise transferred may enable the transferee to general and manage technical change ("know-why"), i e , for carrying out further R&D for innovation and/or adaptation ("Flow C")

A major (negotiable) aspect of technology transfer quite clearly relates to the category of transfer (i e , Flow A,B or C) Within these broad categories, many permutations and fine tuning may be possible in specific contexts The actual category of transfer will naturally relate to the compensation secured by the technology owner, besides other aspects

Modes of technology transfer

Technology transfers may occur on commercial or non-commercial terms, the latter involving concessional terms of payment to the transferer In the present context, while the multilateral financial mechanism may ensure that the recipient developing countries are fully compensated for costs of technology transfer, it does not seem likely that the transferers will be obliged to

[8] "Technology transfer" may be defined as the process by which technology, knowledge and/or information developed in an organization, in a given area, or for a particular purpose, is applied and utilized in a different setting or context

collect less than commercial levels of payments either directly, or through legal amendments diluting the exclusionary power of the relevant IPRs. Transfers of benign technologies under existing global environmental agreements would, accordingly, be properly classed as commercial transfers.

Two of the principal modes of technology transfers on commercial basis are foreign-direct investment (FDI), and licensing of IPRs In the former, the IPR owner realizes her rent from a share in the economic profits of a subsidiary or a joint venture in the host (transferee) country The repatriation of economic profits may occur transparently, or through occult practices, such as "transfer pricing", i e , a non-market price for goods and services applied to affiliates In the latter (licensing), some of the IPRs holders rights may be transferred to the licensee for an explicit consideration (e g , royalty payments), although some alternative arrangements (e g , commitments to buy other goods and services under transfer pricing) may also be employed The extent of IPRs rights transferred may be limited spatially (region), temporally (duration) and in various other ways as well (e g , rights to technologies derived by R & D efforts of the transferee)

There are, of course, other possible modes of technology transfer Once again, were need to note that the mode of transfer is an important negotiable dimension, and much fine tuning is possible within each mode The precise, detailed mode may be unobservable a fact which may furnish scope for strategic behaviour

Incremental costs of Technology Transfer

The last two subsections would have made clear that far from a categorical, binary notion, technology transfer is a process with myriad attributes Negotiable dimensions of transfers include extent of knowledge and information being transferred, mode (e g , FDI or licensing), quantity and forms of compensation, and so on Quite clearly, the notion of "incremental costs" of technology transfer is linked intimately to each of these attributes

All countries, including, developing countries have multiple policy objectives While these include the conventional objectives of growth, economic structure and distribution, quite often the acceleration of indigenous technological capability, both in the general sense of creation of a diversity of technological skills, and more specifically as R&D capabilities in a spectrum of sectors and industries, is a strongly articulated policy concern of developing countries

Accordingly, in specifying a path of growth of the national economy, even if conservation/abatement responsibilities were not in existence, increasing the technological capabilities of the country may be legitimately articulated as a major policy objective Further, in formulating a national conservation/abatement strategy, developing countries would seek at least as complete a level of access to or mastery of the benign technologies as they have (or prospectively hope for) in respect of the earlier technologies In addition, countries may have differing perspectives on FDI Countries may, as a matter of national policy, be permissive, i e, impose few restrictions on forms, practices, or sectors for FDI Alternatively they may seek to regulate such investment in various ways, including by restrictive general norms, or case-by-case regulation If technology transfers for abatement are linked to norms for policies on FDI, developing countries may be unwilling to formulate strong conservation/abatement strategies

The point of the foregoing discussion is that, citing future technological capability concerns, developing countries may seek transfers of benign technologies in depths (levels of knowledge, mode of transfer) exceeding current capabilities in existing technologies Clearly, from the perspective of the multilateral financial mechanism, a "moral hazard" problem may arise That is the financial mechanism would be unable to ascertain the actual prior technological capability objectives of the DC, and conversely, the DC policy makers may seek to accelerate their growth of technological capability over their earlier objectives (i e, without abatement/conservation commitments) For this, developing countries policy makers would seek to negotiate greater depths of technology transfers on less restrictive terms, than if they simply sought to maintain unchanged their original technological capability objectives They may be enabled to do so because the increased incremental costs of the greater depth of technology transfer (e g royalty payments) would have to be met by the financial mechanism If the FM seeks to negotiate restrictive norms for depth of technology transfer (and/or norms for royalty payment as an element of incremental costs), developing countries would have a strong suit, because they could, for the most part, claim that their pristine technology capability objectives were sought to be abridged

It is clear that the different attributes of technology transfer for abatement/conservation would be negotiable between ICs (donors) and developing countries (recipients), perhaps under the aegis of the FM Donors are unlikely to view the FM as a institution with the collateral purpose of enhancing the technological capabilities of developing countries. They may accordingly, seek to negotiate restrictive (low depth) norms for technology transfers to be financed by the FM developing countries may, on the other hand perceive that non-restrictive norms for technology transfers are one way of realizing payments for the positive externalities

garnered by ICs for their (developing countries) abatement/conservation activities, and withhold cooperation if the norms are restrictive. It is difficult to predict the outcome

Macroeconomic Effects

Activities that enhance environmental degradation cover a wide swathe of the total economic effort. For example, climate change is linked to CO_2 emissions, which largely result from energy use, in particular of fossil fuels. Energy is, of course, a ubiquitous input in all production processes, besides comprising significant shares of public and private consumption expenditures Different energy forms are substitutable by each other, and moreover, are substitutes for (or complements of) other production inputs, i e, capital, labour, land Regulation of energy use may thus have pervasive impacts on the economy, in addition to environmental quality, through changes in relative commodity and factor prices, incomes, public revenues, and trade patterns These impacts could lead to changes in welfare levels, income distribution, growth rates, and balance of payments

An assumption frequently made in micro level economic policy analysis is that of *ceterus-paribus* (i e, "all else unchanged") While this assumption helps keep the analysis tractable, and at the level of (individual) project evaluation is not unrealistic, it may be untenable in evaluating large-scale conservation programs An economy wide effort at conservation will very likely lead to changes in relative factor and commodity prices, and this will seriously smear the results of project evaluation In particular, regulatory structures for environmental concerns would need to be established The application of regulatory policy instruments (e g, energy taxes, pollution taxes, tradeable permits) would change incentives (prices) faced by producers and consumers, who may alter their production or consumption choices Further, there may be significant revenue implications, and consequently change in patterns of government expenditures All these changes will be transmitted throughout the economy through market linkages

Such macroeconomic, or general equilibrium effects are not intuitively tractable, even qualitatively, except to a limited extent Policy analysis in such cases must rely on appropriately formulated, large and complex empirical macroeconomic (or applied general equilibrium) models of the national or regional economy Such models may simulate the response of the mimiced economy to the application of policies under consideration, and furnish indications of changes in economic output, welfare, relative factor and commodity prices, savings and investments, trade patterns, besides environmental variables such as emissions levels It should be clear that we are not referring simply to the fact that computations of (social) costs of abatement by a general equilibrium approach may differ (significantly) from that resulting from a partial equilibrium (or conventional cost-benefit) approach. The point is that because of

second order (and higher) effects, a large number of policy relevant economic variables, and not only GDP, would be affected

While such models are costly to develop and require highly skilled researchers to devise and use them, these are not the principal limitations to their use in policy analysis The major problems arise from the fact that such models rely intensively on empirical data and parameter estimates, whose numerical values are uncertain In addition, they incorporate a host of assumptions about the underlying economy, which are a matter of judgement by modellers, reflecting their subjective perceptions of the working of the economy The results of the model simulations may be sensitive both to the numerical values of key parameters employed, as well as to the particular assumptions embodied in the model

Another difficulty arises from the fact that these models by their very intended function, i e, simulating the response of the economy to different policies under consideration, because such experiments cannot be carried out with the real world, cannot be empirically validated, at least in the time frame in which policy making is undertaken Empirical validation, however, is a key litmus test of the accepted scientific method, and its impracticability must abridge the significance of such policy modelling for actual policy making

Macroeconomic impacts of abatement programs are, however, inevitable, and there are no alternatives to formal modelling to gain insights into such effects The limitations of such models, however, mean that the insights from such model simulations should be sought in the causal linkages which are revealed, besides the direction of macroeconomic impacts, rather than their magnitude Even such limited use should however be made only if the structures of the models have been reviewed by peers, and the models simulations are, through sensitivity analyses, demonstrated to be robust over a range of plausible values of key parameters and modelling assumptions

Given that the macroeconomic impacts of large scale conservation programs would be tangible, that they would not be tractable in strictly quantitative terms, and that even their qualitative aspects would be subject to some ambiguity, how can policy making address these impacts? An added complication is that not only conservation strategies, but a large set of policies which address quite distinct policy concerns, for example fiscal balance, may also have macroeconomic impacts, which would be difficult to disentangle from those of the conservation program Thus, while policy models may simulate the impacts of a cocktail of policies and furnish some qualitative insights, it would be impossible to separate the impacts of each of these policies, because these are not additive, but are interactive

To our minds, a feasible policy approach to macroeconomic aspects of abatement strategies must delink issues of incremental costs (including transfers) from macroeconomic aspects In other words, the country must specify its macroeconomic objectives clearly and separately from its conservation goals Policies for macroeconomic objectives must be formulated independently, but it may be in the interests of developing countries if the adoption of actual conservation strategies (with multilateral financial support and technology transfers) are linked to support for the macroeconomic policies themselves It would be important for funding agencies to realize that no developing country government could feasibly formulate and adopt a strong conservation regime without macroeconomic stability or realizing its broader macroeconomic goals Since support for macroeconomic policies comprises a wide spectrum, inclusive of trade regimes, foreign debt, besides bilateral and institutional funding for fiscal stabilization and restructuring, the space for establishing such linkages is indeed very large

Section III
REVIEW OF COST ESTIMATES FROM THE AEI STUDY

As reflected in Section I, the need for arriving at a consensus on a conceptual and mathematical definition for "incremental costs" for GHG abatement is increasingly important in light of the Climate Change Convention However, the perceptions on this concept vary considerably across countries and are riddled with complexities for developing countries This is due largely to the presence of "opportunity costs" in terms of foregone possibilities for economic development In this context even if concessional funding were available for implementing mitigation strategies, we cannot overlook the amortization and interest payments which could impose a considerable burden on the developing economies In addition, an abatement programme may have widespread direct and indirect costs (including transaction costs in planning and implementation) The above issues have already been discussed in depth in the Section I & II

The focus of this section is a collaborative study undertaken at the Tata Energy Research Institute (TERI) with other members of the Asian Energy Institute (AEI) network on developing cost curves for a menu of technologies that can realisticaly be introduced by the year 2000, with the aim of reducing CO_2 emissions

Review of the AEI study

The countries for which this study was undertaken include Brazil, Bangladesh, China, India, Japan and Thailand The objective of the study was to rank and prioritize various options based on the costs and CO_2 abatement potential The options considered can be classified as

- Improvements in energy efficiency and energy conservation
- Switch to lower carbon fuels and greater use of RETs
- Afforestation to sequester atmospheric carbon

The specific cost of each option was based on capital costs and the potential CO_2 savings over the lifetime of the option On these bases cost functions were derived However, the concept of cost varied across the country studies and do not reflect the definition developed in Section I of this paper Besides, the absence of well developed data systems in this part of the world only exacerbates the problem of obtaining good estimates and neat conclusions

The studies from India and Bangladesh for instance focus on the upfront capital costs of each technology, not encompassing operations and maintenance costs nor fuel costs. Hence this analysis was useful in indicating only the order of magnitude of the investments required

for abating emissions. The Brazilian team, on the other hand, had a comprehensive consumers perspective, also taking cognizance of the benefits (energy savings) that may accrue from each option and their perception of costs was equivalent to an incremental cost In particular the following formula was used:

$$CAC = \frac{E + I_1 - I_2(US\$)}{annual\ avoided\ carbon(kg)}$$

where CAC is the cost of avoided carbon

E is the value of annually saved energy expenses

I_1 is the avoided annual investment cost of the old technology

I_2 is the annual investment for the new technology

This difference is obvious from the cost curve graphs (see Annexure 2)

The total investment requirements have been worked out for each country by adding the product of specific costs and the estimated potential CO_2 savings for each technology On the basis of the specific costs and potential CO_2 savings, the cost functions for abating CO_2 emissions have been drawn These cost functions may be viewed as a supply function for CO_2 abatements in each country

Of all the countries in the study, China and India afford the largest potential for CO_2 savings, i e 4,175 and 2,875 mtC respectively On the other hand, in Bangladesh from the available shelf of technologies which can be adopted by the year 2000, the potential for cumulative saving is only about 75 mtC It is reiterated that the savings of carbon in each case are computed over the lifetime of each technology and the cumulative savings are an aggregate of the same Such computations could not be undertaken for Brazil, Iran, Japan, Korea and Thailand A sectoral wise comparison of the technologies that can be introduced by the year 2000 follows

Power sector

The cross-country comparison reveaed that in the electricity sectors of Bangladesh and India, there is considerable scope for reducing transmission and distribution losses, which range from 22% in India to 40% in Bangladesh If these losses were reduced to 16% by the year 2000 in India, an investment of $7 2 billion would be required with an estimated potential reduction in CO_2 emissions of 210 mtC (assuming that the entire reduction in CO_2 emissions is attributable to reduced power generation by coal based thermal plants) On the other hand, if electricity

authorities in Bangladesh aimed to reduce the T&D losses to 25%, an investment of $82 million will lead to a saving of 2 4 mtC. In Bangladesh there is no coal based power generation (It is based on hydro, natural gas and oil) For Bangladesh, the current generation level (7732 GWh) were used to compute CO_2 savings, assuming that all generation saved is attributable to natural gas based plants If the likely generation in the year 2000 is taken as the reference, the potential savings in CO_2 emissions will be higher

In China, energy efficiency improvements in the power sector are envisaged due to hike increase in the shares of pressurized fluidized bed boilers and combined cycle plants (oil based) An investment of $180 million in the former and $192 million in the later may result in savings of 9 5 and 5 2 MT-C respectively By comparison, gas based combined cycle plants replacing coal based plants in India would need an investment of $1 7 billion and save 82 5 mtC

In Thailand, the feasibility of electricity generation from agricultural wastes for rural industries has been identified as an option for limiting CO_2 emissions, with the replacement of wood charcoal and electricity (thermal based) by gas or electricity from agricultural waste gasifiers The specific cost is computed to be $38/tonne of CO_2

Industrial sector

In the industrial sector, the scope for enhancing energy efficiency is high in all countries included in this study, though the particular measures identified in each country differ In the industrial sector in India, improved housekeeping, the installation of energy efficient equipment and better instrumentation may result in saving 88 mtC, at an investment of about $3 5 billion In Bangladesh the package for efficiency improvements which includes combustion control, process improvements, cogeneration and simple retrofits will require an investment of $131 5 million and save 3 4 mtC In Brazil, the suggested package for industries includes better choice of electric motors (in terms of their size), appropriate design changes in the internal electricity distribution network, the installation of small size transformers in parallel with large ones and correction of the load factor, requiring an investment of $1 billion and saving 4 8 mtC The specific costs are as high as $208 40/tC

The specific cost of reduction of CO_2 is the lowest for better housekeeping measures among all measures identified for the industrial sector in both India and Bangladesh ($8/tC in Bangladesh and $14/tC in India) This clearly highlights the attractiveness of introducing such simple, measures

In China the emphasis in the industrial sector is on retrofitting existing industrial boilers and kilns, which will require an investment of $6 3 billion and result in a CO_2 reduction of 252 mtC The specific cost are $19/tC saved in the case of retrofitting boilers and $35/tc of carbon saved by improving kiln efficiency

In all these countries, the industrial sector uses a major share of the total energy supplies Accordingly, steps to improve efficiencies in industry may result in considerable energy savings in absolute terms and consequently reduction in CO_2 emissions

Transport sector

The transport sector in India accounts for 24% of total energy consumption With a decrease in the share of railways in both freight and passenger transport, and an increased share of personal modes of passenger transport, the energy demand in this sector has increased substantially Hence, measures that have been suggested for possible implementation by the year 2000 are

- Enhanced urban mass transport through increasing the bus fleet and introduction of metro rail system
- Increased rail freight movement

The total required investment of $48 billion will save 279 mtC

In Bangladesh, the best way to conserve energy in the transport sector is through improved road maintenance, which is most easy to implemented This would require an investment of $110 million and would save about 1 2 mtC

The Brazilian case is interesting in that transport is a key variable in the solution to minimize carbon emissions. Here transport sector accounts for 32% of carbon emissions Fuel substitution, highway improvements, efficient diesel engines and improvements in vehicle efficiencies are the main ways of solving the problem The highway improvement programme will cost as much as $2,954/T-C as compared for instance to only $92/tC in Bangladesh However, it must be reiterated that these specific costs are not comparable Improved urban transportation through the construction of special lanes for buses will cost as much as $2,147/tC saved.

Residential sector

In the residential sector, improvements in energy efficiency of both cooking and lighting devices has been analyzed However, the devices considered and the fuels used differ across the countries Improvements in cooking devices range from improved firewood *chulhas* in India, to coal saving stoves in China, to *unnat chulhas* (based on woody biomass) in Bangladesh The specific costs vary from $14/tC saved in India to $9/tC saved in China and $5/tC in Bangladesh (again, the figures are not comparable across the countries) It is interesting to note that essentially the same option will save only 2 mtC in Bangladesh, 6 mtC in India and as much as 305 mtC in China This difference between Bangladesh and India on the one hand and China on the other is due to the fact that the fuels used in the devices (wood and coal respectively) are different

The lighting devices that have been considered also vary significantly In Bangladesh improved kerosene lamps (*unnat koopi*) is the feasible option, while in India the technologies identified that can be adopted by the year 2000 are fluorescents, both tubes and compacts In Brazil too, experts feel that by the year 2000, the stock of residential lamps will comprise 50% improved incandescent, 30% fluorescents and 20% compact fluorescents To achieve this, an investment of $1,271 million will save 2 33 mtC, with the specific cost of $545/tC In India, on the other hand, if we assume that it is possible to replace 50% of the incandescents by fluorescent lights, the specific cost will be $12/tC and if 50% incandescents are replaced by compact fluorescents, the specific cost will be $85 82/tC The specific costs are much lower in India because a major share of the electricity saved is from coal (70%) and hence the volume of carbon emissions saved is greater In direct contrast, in Brazil, 90% of the electricity generated is from hydro sources implying a lower carbon saving The difference in specific costs can also be attributed to the varying approaches adopted in the two country studies While Brazil considers tube fluorescents and compact fluorescents in conjunction with incandescents, the first two options are considered separately in the India study

Afforestation

One of the best ways of assimilating CO_2 emissions is through afforestation In India, a stated government policy objective is to afforest one-third of the land area by the 2000 year, implying that 70 million ha will be afforested during this decade On the other hand, China aims to afforest 16-17% of its land area, where transcutes into an area of 48-63 million ha In Bangladesh the potential area that can be afforested is 2 64 million ha The specific investment costs are quite comparable ranging from $19 2/tC in Bangladesh, $26 3/tC in China, and $27/tC in India.

The Brazilian case is unique. An extremly high proportion of total carbon emissions are due to deforestation, these however are difficult to calcutlate presicely Unlike in other developing countries, this deforestation is not strongly related to the use of fuel wood for energy. It is primarily due to grazing, agricultural and logging activities. Experts from Brazil claim that afforestation/reforestation " with conventional relatively homogeneous plantations to sequester carbon in biomass may result in a relatively small part of the reduction of net carbon emissions" The short-term emphasis should therefore be on stemming deforestation and in reorienting electricity generation policy The high priority assigned to hydro projects should be modified and the pace of exploitation of the hydro potential in the Amazon should be arrested This may imply an increase in carbon emissions as a result of higher thermal power generation, but this increase is likely to more than compensated for by consequent reduction of deforestation

In Thailand, energy plantations have been identified as a measure to limit CO_2 emissions since these would imply no emissions from deforestation for energy purposes This measure results in a saving of 11 9 mtC/year and costs between $644-$749 million Accordingly, the specific cost ranges from $54 to $63/mtC

The cheapest options in the different countries vary For example, in India coal washing is cheapest in terms of specific cost per tone of carbon saved In China the dissemination of coal saving stoves to rural households is the cheapest option and in Bangladesh the improvement in the efficiency of firewood *chulhas* has the lowest specific cost In Brazil, improved incandescents is the best option

In Iran, there are plans to improve efficiency in electricity generation, to increase the share of public transport in passenger movement, to replace gasoline by LPG in buses, and afforestation, which will facilitate CO_2 reduction However, cost estimates are not available

Similarly, the Korean economic development plan has laid down certain energy policy measures with a view to achieving the objective of a relatively clean environment These include the expansion of gas use in urban areas to replace the existing fuel, anthracite, raising the proportion of low sulphur diesel and unleaded gasoline, and a strict enforcement of environmental standards for coal fired plants and coal briquette manufacturers The costing of these measures could not be undertaken

The case of Japan is entirely different. Not only it is the only developed nation among the countries in this study but also, owing to intensive measures to conserve energy, industrial restructuring and the introduction of nuclear energy and as LNG, CO_2 emissions have declined

at an average annual rate of 0 1% from 1973-85 However, after 1987, Japan has witnessed further economic expansion marked by the revival of energy intensive industries Consequently, energy demand and CO_2 emissions have increased To limit CO_2 emission in the future, Japan must develop and introduce extremely advanced technologies But information in this area is uncertain and limited Hence Japan's principal contribution in abating CO_2 may lie in transferring the already established technologies to other countries in Asia which have yet to achieve Japanese energy and CO_2 intensity levels of intensities

The highlights of each of the country studies are summarized in the Annexure II

The impacts of emissions of CO_2 (and other GHGs) on the global climate through the greenhouse effect have generated an international debate on the possibilities of limiting these emissions While the countries of Asia and Brazil have not been major contributors to the build-up of GHGs in the past, they are likely to be so in the future In order to sensitize policy makers on the menu of options available to limit these emissions from their economies, analysis and research by credible institutions located within their countries is necessary The AEI study has taken a first and important step in this direction

However, it should be noted that the list of options identified and analyzed in each of the country papers is not exhaustive Only those options which could realistically be implemented by the year 2000 have been considered Furthermore, the cost estimates represent only broad orders of magnitude since they have been quantified to a first approximation A rigorous study of each of the options identified is necessary to get more precise numbers Moreover, a uniform methodology employing consistent and comparable definitions of costs should be adopted by all countries in order to make the inter-country comparison more meaningful

Section IV
INSTITUTIONAL DESIGN AND CAPABILITY

The GEF -- the Initial Years

The Global Environment Facility arose out of the growing perception that an institution was required to provide concessionary financing to developing countries in situations where a country would bear the costs for environmental protection and a part of the benefits would accrue to the global community The idea was proposed by France -- and supported by Germany and other nations -- at the World Bank Development Committee discussions in 1989 As a result, twenty five developed and developing nations agreed in November 1990 to establish a Global Environment Facility (GEF), which is run jointly by the World Bank, the United Nations Development Programme (UNDP), and the United Nations Environment Programme (UNEP)

The goal of the three-year pilot program (which is how the GEF began operation) wa to provide resources to help finance innovative programs and projects affecting the globa environment that would not normally be funded, and to do so in a manner that examined & considered how developing countries could deal pragmatically with these issues, at low cost, an without impeding development It was hoped that the relevant experience derived from it operations in dealing with global environmental challenges would be taken into consideratio in the World Bank's regular operations The total financing available, $1 5 billion, was to b provided by a number of donors in tranches over a three year period

Four areas were initially selected for the operations of the facility [9]

Protecting the ozone layer Developing countries were to be assisted in making the transitic from the use and production of chlorofluorocarbons (CFCs) and other gases -- which contribu to the deterioration of the ozone layer -- to available substitutes and alternatives

Limiting greenhouse gas emissions Areas for action by the facility include the adoption cleaner fuels and technologies in the energy, agriculture, and industry sectors, as well reforestation and forest conservation

Protecting biodiversity The richest remaining sources of ecological systems and diversity species -- which contribute to a wide range of goods and services, including harvestat medicines or industrial products, genetic resources for food production, and the regulation climatic and rainfall patterns -- are in the developing world The facility was to support effo to preserve specific areas

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[9] *World Development Report 1991*

Protecting International waters The facility was to support programs to enhance contingency planning for marine oil spills, to abate industrial and waste water pollution that affects international marine and freshwater resources, to improve reception facilities for removing ballast from ships in ports, to prevent and clean up toxic-waste pollution along major rivers that affect international watercourses, and to conserve unique water bodies

All developing countries with ongoing UNDP programs which also had a per capita GNP of $4,000 or less in 1989 rare eligible for GEF funding for investment projects and technical assistance At present, all proposals for GEF funds are channelled through the governments of these countries to the World Bank (for public sector projects), the International Finance Corporation (for private sector projects) or UNDP (for technical assistance or demonstration projects) The maximum amount that can be allocated to a single project is $10 million for free standing projects and $30 million for projects with co-financing of multilateral development banks

While most projects are country specific, some regional projects (biodiversity in adjacent areas in two countries, for instance) also qualify Projects were intended to be designed so as to ensure that there was a clear distinction between GEF and regular development programs and projects In addition, to qualify, projects must be consistent with global environmental conventions and with country-specific environmental strategies or programs, and be both cost effective and of high priority from a global perspective

The GEF was to be composed of a core fund, to which contributions on a voluntary basis and in convertible currency could be made in the form of grants, and a cofinancing agreement, funded through concessional loans or grants provided on a bilateral basis, to confinance activities supported by the core fund At the end of the fiscal year 1991, contributions to the GEF amounted to about $871 million

In 1992, the GEF established a set of priorities for greenhouse warming projects and also laid down principles to guide project design [10]

Principles

- More technologies are needed to offer options for reducing emissions at least cost
- GEF funding should encourage promising but unproven technologies when the technology, economics, or market conditions are not yet "right".

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10 *World Development Report 1992*

- Successful technologies will be those that show potential for widespread use and could eventually attract investment from conventional sources

Priorities for support

I End-use efficiency

- Reducing energy intensity of basic materials processing
- Efficient motors and drives
- Irrigation pumpsets
- Lighting and water heating
- Vehicle fuel use

II Reduction in the emissions intensity of energy production

- Renewables such as photovoltaics, solar thermal, and wind power
- Biomass gasifiers/gas turbines
- Sustainable biomass production to replace fossil fuels
- Advanced, efficient gas turbine cycles
- Microhydropower
- Fuel switching to natural gas

III Non-carbon-dioxide emissions reductions

- Urban and rural waste treatment
- Reduction of flaring and venting of natural gas
- Reduction of releases associated with coal mining

IV Generic areas

- More efficient production, transmission, and distribution of energy
- Slowing deforestation
- Sequestering carbon dioxide (for example, afforestation)

One of the most crucial questions that United Nations Conference on Environment and Development (UNCED) posed was that of the structure and functioning of the international financial mechanism to oversee financial transfers envisaged in the two conventions signed at Rio With special reference to the GEF, pledges were made for a continuation of the Facility from mid-1994, when the Pilot Phase comes to an end It is expected that about $1 billion will be made available annually, of which about $500 million annually would be for reducing or slowing the growth of GHG emissions. The actual amounts made available (and the distribution of the same) will depend on a number of factors. Among the most important of these will be

assurances that the future phases of the GEF will be efficient and effective in meeting global environmental objectives

Paragraphs 1-3 of the Climate Change Convention relate to the financial mechanism Article 11 (1) defines a mechanism for the provision of financial resources on a grant or concessional basis This is to be accountable to the Conference of the Parties established under the Convention The Conference of the Parties is to decide its policies, programme priorities and eligibility criteria The Article goes on to say that the operation of the mechanism will be entrusted to one or more *existing* international entities This mechanism, under Article 21 which deals with interim arrangements for the financial mechanism, is to be the operated by the GEF, during the period between the signing of the Convention and the completion of the first Conference of the Parties

Paragraph (2) of the same Article states that the financial mechanism shall have an "equitable" and "balanced" representation of all parties within a "transparent" system of governance For the GEF to carry out its role in accordance with the guidelines in Article 11, its restructuring becomes an issue [11]

Article 4 of the Convention lays out the specific but differentiated commitments that apply to developed and developing country parties to the Convention Article 3 Paragraph 3 requires that developed country parties

> *"shall provide new and additional financial resources to meet the agreed full costs incurred by developing country parties in complying with their obligations under Article 12, Paragraph 1 They shall also provide such financial resources, including agreed full incremental costs of implementing measures that are covered by Paragraph 1 of this Article and that are agreed between a developing country Party and the international entity or entities referred to in Article 11, in accordance with that Article "*

Under Article 4, Paragraph 1, a large number of activities are eligible for funding by the GEF As has been argued elsewhere, the breadth of activities included under Article 4 and the more that 100 developing country parties to the convention, the aggregate potential demands

[11] Similar arrangements exist in the Biological Diversity Convention Article 21 (1) states that the Conference of the Parties shall determine the policy, strategy, programme priorities and eligibility criteria relating to access and use of financial resources collected under the Convention It envisages that the mechanism shall operate within a "democratic" and "transparent" system of governance Article 39, on interim financial arrangements, again designates the GEF with the job It specifies that the GEF must be fully restructured in accordance with the requirements of Article 21

for financial resources could be enormous[12] The potential costs of measures will be much larger than the expected near term replenishment of GEF funds

Obviously, then, reform in the GEF's institutional structure is required There are broadly two sets of measures that are currently being advocated in order to reform the GEF and make it more sensitive to requirements for GHG abatement and to enable the facility fulfil its mandate under the Climate Change Convention The first call for reform within the current structures and systems established by the GEF (as referred to in the previous paragraph), and the second set of measures advocate changes in the basic institutional design of the GEF

The first set of changes, involving limited internal restructuring, would have the GEF develop a new set of operational guidelines for responding to the requirements of the Convention As mandated by the Convention, these guidelines would have to establish a transparent, equitable and systematic method of calculating incremental costs and institute a system to ensure that agreement is reached between the GEF and the country concerned The GEF would have to establish a procedure for rationing limited resources among the Parties and among proposed projects in order to capture the greatest global environmental benefits from the limited funds that are likely to be available, and at the same time ensure adequate regional balance in disbursements

The choices among the second set of options are few Developed countries are already touchy about the one-country-one-vote decision making procedures that exist in the UN General Assembly and other organizations in the UN system, and will attempt to resist moves towards any such arrangements within the GEF at the present time As a result, (of such one country one vote democratic arrangements in the UN system) donors often prefer to channel such contributions through alternative (e g , bilateral) funding arrangements that give them a greater say in how funds are used Other options for reform base themselves on different types of weightage systems, such as those based on, for instance, the size of the economy and population (or a combination of such indicators)

The issue of equal rights of voting and participation, however cannot be wished away Developing countries, feel, legitimately, that if they are to alter development strategies and move to a less GHG intensive path, they should have a greater say in the allocation of resources, even if they themselves are the recipients of such resources Further, the negotiations leading up to the Convention took place under the aegis of the United Nations and in particular under

12 See the background note to this Work hop

General Assembly rules These rules, of course include one-country-one-vote provisions, and it is therefore unrealistic to expect that any financial arrangement which is a creature of the General Assembly (including a provisionally designated mechanism like the GEF) should function in disregard of such rules Even if the current institutional structure does not permit similar democratization under the World Bank/IMF type system, the Facility should seriously consider measures that would lead to the institution of more democratic and transparent decision making processes Otherwise, its status as the designated financial mechanism may come into serious question

Thus far, only the EC has evolved a decision making system for determining environmental rules and funding priorities Otherwise, in international treaties, governments carefully negotiate who sits on decision making bodies and how votes are calculated, in addition to narrowly circumscribing their scope

The Montreal Protocol Fund

The only truly multilateral exception to this rule is in the policy commitments and international transfers that have been linked to the Montreal Protocol on ozone depletion The Protocol specifies a decision making process for disbursing financial assistance A 2/3 majority of a 14 member executive committee, which must exclude a majority of its 7 members receiving financial assistance and 7 members providing it is needed The Protocol Fund is financed by those not receiving assistance, based on the UN scale of os assessments The executive committee approves allocations among the three administrating agencies (which are the same as in the case of the GEF) and all country programmes in excess of $500,000 It also develops criteria for project eligibility, including the incremental costs to be covered by the Fund, and reviews performance\reports of the activities it supports

Some Options for Reform

Private Sector Involvement

Since many actions towards GHG abatement could involve changes in the way private enterprises function, it may be judicious to involve the private sector, perhaps in the form of chambers of commerce and manufacturers associations in the GEF decision making process at least initially as observes To make the GEF's global warming activities more businesslike, it is suggested that internal decisions should be taken by a small independent team, operating within clearly defined guidelines This team should consist of highly qualified private and public sector executives from both developing and developed countries The Business Council on

Sustainable Development has been suggested as on such organization that could be involved in the selection and financing of such executives

The Rules of the Game

There is a widespread lack of information in both the public and private sectors about the principles and practices of the GEF. In the public sector, there is little if any knowledge of the principles and workings of GEF among most national, provincial and local government officials Knowledge of GEF in the central government is usually limited to a small minority of officials in the finance, environment and external relations ministies and the environmental protection agency or equivalent body Moreover, such agencies or bodies typically have few resources and little influence on major investment decisions which could have significant effects on GHG gas emissions

While in principle, governments can submit project ideas to the GEF, in practice it appears that most investment projects currently financed by the GEF are initiated by multilateral development agencies Yet, when the possibility of changing the principles and practices of GEF was raised, many government officials saw the opportunity for taking advantage of the changes At the Rio summit last June, the majority of the developing countries clearly stated a need for open and transparent procedures with the GEF and a greater input from the developing countries in the project identification and selection process

The method of obtaining GEF allocations should be simple, rapid, low-cost, and transparent, easy to understand and widely publicized Under the Pilot Phase of the GEF "all projects are screened to ensure that they meet the basic GEF criteria Investment projects undergo a technical review by a panel If the project is cleared, it is submitted to the implementation Committee, (whose) role is to choose a group of projects that represents a balance among the regions The projects selected by the Committee are then forwarded to the participating governments (i e , donors) for review at their biannual meetings After review by governments, projects return to their sponsoring agency for further preparation, appraisal and final approval according to each agency's regular procedures" This process, as may seem apparent, is time consuming Also, present GEF eligibility criteria for allocations are seen by many as restrictive in terms of the strictly country based allocations and project\loan driven distribution practices

For more efficient functioning, clear rules should be established and announced on the conditions for applications; on the timing of initial responses to incoming applications for GEF funds, on the schedule for the assessment of potentially viable proposals, and on the expected

date of approval or rejection by the GEF decision-making team Finally, decisions taken on GEF allocations should be open to public scrutiny The decision-making team should issue regular summaries of all decisions taken There are also concerns about what people perceive as the inadequate linkage between GEF allocations and the achievement of specific targets of GHGs In particular, there concern about the lack of a system to establish priorities among all potentially beneficial projects or activities

To get around some of these problems, it has been suggested that there should be a strong relationship between GEF allocations for reducing and slowing the growth of GHGs and a country's or entity's achievement of this objective Recipients of GEF allocations should be required to achieve specific target reductions or slower growth rates of emissions

Decentralization

Perhaps the most constructive proposals relate to procedures that would bring about a degree of decentralization in the functioning of the GEF Measures for promoting energy efficiency programmes, technology development in widely disparate conditions and other actions often require decisions by a large number of individual actors The GEF its current framework, is not adequately equipped to institute decentralised decision making To facilitate this process, it is suggested that within each country eligible to receive GEF funds, the government should nominate or set up a specific office or agency that would act as a conduit for proposals to the GEF The unit could also disseminate information about the principles and practices of the GEF with respect to global warming The national environmental protection agency or the local UNDP or World Bank office could be the designated agency

Section VI
CAPACITY BUILDING

In this section we focus on the important subject of capacity building in the context of the GEF's role in general and the implementation of mitigation strategies assessing the incremental costs that would be applicable. It needs to be emphasized that any action directed at mitigation measures for improving the global environment have to be seen against the backdrop of environmental issues in general and the concept of sustainable development The issue of capacity building is totally relevant to the understanding and assessment of incremental costs, because several measures that would need to be implemented through the GEF mechanism in developing countries would be successful only if local capacities are built to ensure their successful implementation In fact, even the identification and design of appropriate measures would depend entirely on the capacity of local organisations to handle these tasks The measures that GEF would be dealing with essentially involve the implementation of new paradigms of development and these necessarily involve new patterns and modes of decision making at every level, right from national governments to the most basic grass-root levels Perhaps some of these issues could have been tackled through more innovative programmes in the pilot phase of GEF, but at any rate their non-inclusion in any future agenda would be a severe weakness that must be avoided at all costs

Protection of the environment, whether at global or local levels, cannot take place if a society is impoverished and deprived The removal of poverty is an essential prerequisite for environmental protection The development of local capabilities and institutional strengths lies at the core of promoting development in a sustainable manner in the poorest regions of the world Capabilities and capacities have to be strengthened not only in the scientific and technical field but also for planning at the national level and, of course, at the most decentralized grassroots level as well In this regard the record of several multilateral and bilateral organizations has been less than satisfactory The favoured approach has been to engage a group of consultants from countries in the North, often with mediocre skills and inadequate familiarity with local conditions, to carry out studies and consulting assignments by "parachuting" them into a country for a few weeks at the end of which they are supposed to have identified all the development problems of the country and also to have evolved solutions to eliminate them What is left generally is a voluminous report on strategy which is often neither of value as a professional exercise nor of direct use to the organizations in the country for devising local plans and investments In the technological field, again there has hardly been an attempt to involve local institutions, for instance, in the development of renewable energy devices In the absence of such an approach, technological change does not get endogenized

There was, perhaps, a rationale for a large quantum of external "technical assistance" for the developing countries 40 years ago, when most of them emerged from colonial rule Such conditions do not exist any longer, and several countries in the Third World were well equipped to undertake complex developmental tasks even at that stage Unfortunately, a web of vested interests has developed over the years, which sees development assistance programmes as providing opportunities for continuing with the dependence on expatriate consultants on an interminable basis But if major changes are in the paradigms of growth and development are to take place -- which are essential for protecting the global environment -- then a major change in favour of reliance on local groups is now overdue

There is today a powerful need for setting up a network of institutions in the developing world and providing them with adequate resources for research and development on environmental subjects and renewable energy technologies and devices and their dissemination If this approach is not adopted, developing countries would be constrained to follow the fossil fuel based path that developed countries have even when there is a compelling economic reason for other choices based on renewable energy sources, which are becoming increasingly relevant with advances in technology and increasing environmental costs, both globally and locally But resources would again have to be found for such a programme of networking which is not only beyond the capacity of the developing countries to harness, but which developed countries have a moral responsibility to provide, at least for global environmental reasons National governments and even non-government organizations have a major role to play In these efforts, while multilateral organizations and mechanisms such as the GEF can play a useful catalytic role, it would be up to societies in the developing countries themselves to initiate action

In the last two years, and particularly since the UNCED conference in June 1992, the term capacity building has been used extensively by development organizations, national governments, scholars and academics Yet, several misperceptions and misinterpretations on the term capacity building are prevalent on a wide scale, and different entities view capacity building in different lights Since the subject is of considerable importance to the implementation of the post-Rio agenda, it is essential to throw light on this topic and to define a set of programmes and activities that would be required to attain the aims of capacity building One major misperception which seems to dominate the development jetset, particularly in the countries of the North, is based on the belief that capacity building is an exercise to be undertaken only in developing countries But it is clear that capacity building in the developed countries is important and, perhaps, far more complex than in the countries of the South This is so because while in the developing countries new skills and capabilities are required to be generated, in the developed countries there is a far more difficult task to implement in changing

old attitudes, values and directions to be replaced with a new set of lifestyles and structures In discussing capacity building in this paper, we are focussing largely on the case of India, drawing on specific examples in this country, but the issues to be covered are generic in nature and apply to a great extent to all developing countries

A few recent meetings and discussions have taken place in different parts of the globe on actions that need to be taken as a follow-up to the Rio Summit and the subjects on which agreement was reached there as well as those subjects on which attention was not provided or agreements were not reached in Rio In October 1992 a Post-UNCED Seminar on "Environment & Development Policy Issues in Asia" was held in New Delhi This seminar was attended by researchers and policy makers drawn from Asia as well as from a few developed countries The purpose was to analyze the Climate Change Convention, the Biodiversity Convention and Agenda-21 with a view to arriving at perspectives from the Asian region for actions required at both at national levels as well as on a regional basis for Asia as a whole In the final recommendations of the conference the issue of capacity building was addressed at some length and articulated as follows

> *"There is a marked asymmetry between industrialized and developing countries in their respective capacity for formulating informed and cogent positions during the negotiating process The asymmetry in capacity may have influenced the outcomes of the negotiations leading to the Rio agreements The agreements themselves were negotiated in a relatively short period of time with the explicit objective of adoption at the UNCED The whole process extended to a little more than a year This was too short a period for building up institutional capacities in the several disciplines which are germane to formulating negotiating positions "*

> *"Domestic capacity needs to be built in the relevant scientific disciplines, institutions, as well as skills in policy analysis and policy making This process must commence expeditiously and involve the greatest measure of international cooperation between industrialized and developing countries on the one hand, and developing countries themselves on the other The future course of negotiations must allow for this process to get sufficiently under way "*

> *"The initiative for such capacity building must emanate from developing countries themselves, both individually as well as through their groupings, which may be regional. The scope for cooperation between developing countries in this respect should not be underestimated. Such cooperation may rely on professional networks and associations in developing as well as industrialized countries, besides intergovernmental organizations It is essential for the IPCC and the Commission on Sustainable Development to initiate specific actions for capacity building in developing country on global environmental issues, and to ensure utilization of these capacities in their deliberations "*

The central concern expressed in these recommendations is confined mainly to the arena of global negotiations, and capacity building must be undertaken urgently in this context Governments, research organizations and [illegible] the media need to be involved in such a

programme However, in the pages that follow, we have attempted to cover capacity building issues in the wider context of integrating environmental factors in development plans and activities

National governments must utilise the ability of institutions to develop and strengthen networks with other countries and institutions in both developed and developing countries This is particularly necessary in dealing with global environmental issues and assessing the viability and merits of transfers of finance and technology that are to take place through various mechanisms, particularly the GEF, in the coming years The primary role and most effective action that such networks could take collectively is in keeping multilateral and bilateral development organizations honest in their interpretation and implementation of capacity building activities Adequate but modest funds should be sought for carrying out an ongoing scrutiny of development assistance programmes for capacity building, of which we are likely to see an avalanche in the coming years, so that the kinds of distortions referred to earlier do not continue and a mockery is not made of well-intentioned capacity building efforts that would form part of development assistance programmes

How should capacity building be channelized if we wish to install capabilities and infrastructure for effectively addressing environment and development problems in the countries of the South? Firstly, we have to critically ask whether the traditional approach to institution building, namely that of creating or strengthening public institutions, is the best approach to follow The answer is quite obviously no, because governments have certain inbuilt constraints in functioning solely on their own in

- effectively integrating environmental considerations in development programmes,
- creating awareness at the grassroots levels, so that environment and development becomes truly a people's movement,
- providing adequate resources for environmental protection, accustomed as several ministries and departments are to conventional methods of spending that merely emphasize investments in hardware, large projects and programmes

It is necessary, therefore, to conceive of capacity building efforts as strengthening institutions and organizations outside the government, because through the pressure and the innovative inputs that non-government organizations can provide, ministries and departments not dealing with environmental subjects themselves would have to improve and attain higher levels of accountability in this general area But we must identify the types of actors that would be most effective in bringing about the change that is required for preserving the planet and

ensuring the welfare of the poorest of the poor. For, in the ultimate analysis, unless poverty is eliminated, environmental protection would not take place and development would remain merely a pronouncement of words without action. We would like to propose a clear definition, though certainly not a separation, of three sets of actors that would form the core of capacity building activities. These are:

- Non-government organizations (NGOs), who as the term has now come to generally indicate are activist organizations and who articulate problems and issues, acting as a strong pressure group for ensuring that unfair advantage and huge economic rents do not accrue to special interest groups at the cost of people at large
- Grassroots organizations (GROs), who are basically activity based organizations actually implementing programmes in partnership with local organizations, people's groups and others, so that development takes place in harmony with environmental protection
- Non-government research institutions (NGRIs), who can be described as think-tanks not of the ivory tower variety, but groups of individuals who are practical in their approach and empirical in the analysis of policies and programmes Given the great lack of effective think-tanks in the developing countries, it is critically important that NGRIs be strengthened appropriately so that they provide a credible option for policy analysis and formulation, based on research capabilities outside of the government but not necessarily separated from the government

The reason why NGRIs as a specific group of actors need to be supported and strengthened is because in the developing countries (as should certainly be the case in the developed countries as well), there is an urgent need for change in direction in development strategies and the articulation of new paths to of growth This would require substantial changes resource allocation patterns, the institutional arrangements for implementing development programmes and the formulation alternatives in the very structure of the economy No better agent for change on these subjects can be conceived of than local and domestic research institutions, who while working at the frontiers of knowledge and research capability, are in tune with local conditions, including culture, social values, resource endowments and existing skills The development of NGRIs, which the proposed network could focus on as a priority subject would require much closer and more frequent interaction between research institutions and the government, from which benefits would accrue to both sides Government would gain from ongoing analysis of problems and possible solutions as well as new ideas which a thank-tank can produce far more effectively than those who are engaged in day-to-day decision making. Research institutions would gain by acquiring a practical orientation and viewing real life problems in a larger development context rather than in narrow sectoral terms

What is proposed in capacity building efforts in the developing countries, therefore, is a three tier approach involving NGRIs, NGOs and GROs It is quite possible that an organization or group combines all three sets of roles and activities, but any one agent working in isolation of the other two is likely to be less than effective NGOs will remain only activists and eco-fundamentalists if they do not interact with NGRIs and GROs Likewise NGRIs would remain theoretical ivory tower and armchair analysts if they do not interact with the other two sets of actors And, finally, GROs would not understand the problems of resource allocation and their efficient utilization or the inter-play of interest groups in a democratic society, if they remain lost in the field without reaching outwards to the other two sets of actors

Essentially capacity building requires the launching of movements that would effectively integrate environmental concerns with development activities In this approach, however, effective use has to be made of the most capable agents and mobilizing the effort of those who are most likely to succeed For example, if we take up the challenge of developing countries shifting to a more sustainable energy system, a challenge that India must accept as early as possible, a range of actions would need to be launched specifically including

- Macro policy analysis and advice - governments, legislators, leaders of public opinion would have to be educated on the benefits of efficient use of energy, greater use of renewable energy sources and the role of innovation in changing existing patterns of energy consumption The policy analysis package in this case would go far beyond the energy sector, because solutions lie in devising new and energy efficient transport systems better design and construction of buildings, revised approaches to the design of habitats and the use of space in human activities, new technologies for agriculture and the like Since energy consumption patterns in the developing countries basically emulate the experience of developed countries, a change in direction spelling out the implications for financial and capital requirements, new institutions and organizations would have to be included As mentioned earlier, this is an area where so much needs to be done in the developed countries themselves and this, therefore, represents an area where close partnership is possible between research institutions in the North as well as the South
- Actions at the non-government level - This would require, for instance, motivating and helping corporate organizations to carry out energy audits and implement energy efficiency improvement programmes For non-corporate organizations, the effort could involve information dissemination programmes, influencing local groups on taking sustainable energy decisions and, in general, working closely with organizations that are key decision makers and major consumers of energy such as transport organizations, etc

- Grassroots activities - These could include efforts both at producing energy in a sustainable manner, such as biomass plantations and, of course, providing technological solutions for efficient use of energy in households, farms, small production units, etc. GROs can also play a vital role in creating awareness, influencing the adoption of new values in the use of energy, and, in general, bringing about a change in lifestyles to move society on to a new energy path This is an activity that is highly relevant to the developed countries as well, and church communities, neighbourhood groups, etc can play a useful role in this regard. In India, the experience of the literacy movement described earlier, would be a good model to adopt for grassroots action in the energy field.

Against the discussion presented above, it is proposed that the following broad programme of capacity building be pursued in India, particularly in the light of the agreements that came into existence at UNCED in June 1992

Global

Capacity building to tackle global environmental challenges - Capacity in this area is essential for addressing global environmental problems and to equip developing countries with the right level and type of expertise for addressing the task of negotiations under the Climate Change Convention, which has come into existence after UNCED at Rio In particular, the Climate Change Convention requires the developed countries to bear the "full agreed incremental costs for mitigation for greenhouse gases", and this is a subject which rightly should be agreed on jointly between developed and developing country organizations The concept of cost, of course, is not simple and would require considerable research, extensive collection of data and the resolution of methodological problems as an essential prerequisite to producing useful outputs There is a danger that with the growing global interest in quick numbers and pressure from several funding organizations to arrive at cost estimates for ranking opportunities, several misleading and inaccurate estimates of costs may be produced to serve the very limited purpose of global negotiations and financial transfers However, such methodologies cannot be developed overnight, and would probably follow an evolutionary process In this context it would be useful to mention the work of the Asian Energy Institute (AEI) which has developed order-of-magnitude estimates of costs for a number of member Asian countries and Brazil.

On the basis of analysis carried out by the Asian Energy Institute as summarized earlier in this paper, one can identify several target sectors and activities as well as target technologies which would be relevant to the assessment of mitigation measures and their costs. A cross country comparison reveals that in all the countries included in the study the industrial sector

consumes a major share of the total energy supplies Therefore, improvements in energy efficiencies in this sector could lead to significant savings in CO_2 emissions Obviously the particular measures adopted differ across countries For example, in India improved housekeeping, installation of energy efficiency equipment and better instrumentation may well result in saving of 88 million tonnes of carbon (mtC) at an investment of $ 3 5 billion. In Brazil the package for the industrial sector includes better choice of electric motors (in terms of their size), appropriate design of the internal distribution electric network, installation of small size transformers in parallel with the large ones, and correction of load factor, requiring an investment of $1 billion and saving 4 8 mtC

What is mentioned above is purely illustrative of priorities in sectors and activities which would need to be tackled in any capacity building effort in the developing countries, but a research agenda is perhaps best evolved through some interaction between researchers and policy makers Also a research agenda once established may require frequent changes and modifications over time, and it is important for organizations and institutions to network with other institutions, particularly in other developing countries

The other area in which expertise would need to be established in some developing countries would be in respect of the implementation of the Montreal Protocol Among all the developing countries, the importance of this subject is very large for India, which is a manufacturer of CFCs, and is also exhibiting rapid rates of growth in the stock of air-conditioners and refrigerators, etc The changeover costs from CFCs to substitutes in India, as in other developing countries, would include the costs of retooling of industry, changes and design of equipment, and, of course, the costs of substitutes that are to be used in compliance with the Montreal Protocol Disputes are likely to occur between the magnitude of these costs to the developing countries, since the developed countries are due to provide full costs of changeover as specified in the Protocol Capacity building in this case would involve research institutions, industry and of course, government

Local

The development of capacity in relation to local environmental problems requires the ability to carry out environmental impact assessments of a range of activities right from the generation of power and establishment of industrial units to cooking and household activities involving the use of non-commercial biomass fuels Capacity building for improvements in the rural cooking cycle are discussed later, but it is important to observe that for environmental impact assessments, capacity building measures would require:

- The development of expertise in consulting organizations, research institutions and independent bodies who would increasingly be called upon to assess the environmental implications of projects, particularly with growing public awareness. The Sardar Sarovar project in India is a good example where the wisdom of organizations such as the World Bank, the Government of India and State Government of Gujarat has been called into question by a popular grassroots movement opposed to the project
- Training of engineers and managers dealing with a range of industrial projects including those involved in the production of energy It is not enough to find fault with a project once it has been conceptualized and designed Environmental considerations have to be integrated at the design stage itself, and this would require a massive educational effort involving those who are involved in the identification, design and implementation of such projects
- Information dissemination and awareness creation - Environmental considerations would require a great deal of transparency of decisions in a number of activities and educating the public on what is rational and what is not At present, unfortunately, there is a large gap between those who are involved in the implementation of projects and the NGO community that opposes all manner of economic activity The public has to be informed about rational choices and their costs and benefits which translate physical environmental measures into economic terms The capacity of organizations and institutions to convert complex analysis into simple information is a subject of great importance to the implementation of Agenda-21

Rural

The problem of rural areas and capacity building to ensure the sustainability of natural resources is characterized by special sets of problems Much of the degradation of natural resources in rural areas, which is inhabited by the vast majority of the population of India takes place on account of the pressure of fuel and fodder needs of the poor Of these, perhaps fuel problems are the most acute in several parts of the country In fact, India could develop innovative solutions that are relevant to biomass energy problems round the world, which are growing in seriousness and severity

In order to assess the dimensions of this global problem from the perspective of a transition to conventional energy sources it has been estimated that the total consumption of traditional fuels worldwide is currently $18\,726 \times 10^6$ TJ. The efficiency of use of this quantity is generally at a level of 8%, yielding, therefore, useful energy output of barely $1\,498 \times 10^6$TJ If this quantity of traditional fuels was to be replaced by conventional fuels, which normally would permit a device efficiency of 50%, this could be achieved through a consumption of 35 78

million tonnes of oil equivalent (MTOE) of petroleum products annually In other words a total consumption of about 1 2% of the total world production of petroleum would be sufficient for reducing 50% of the traditional fuels used throughout the world At a cost of $ 20 per barrel of petroleum this would require a total expenditure of around US $ 5 billion annually Such higher consumption of petroleum products in several countries would involve import of refined products, particularly kerosene and LPG, but in some cases there may be a preference for enhancing indigenous refining, which would involve additional investments in new refinery capacity The government or the petroleum industry in the country concerned would have to mobilize such investments as required In addition, consumers would have to make investments in new stoves and connections to use the petroleum product in question for reducing traditional fuel use Assuming costs that are applicable to India, we have estimated the total level of such private investments of be somewhat in excess of US $ 2 billion on a global basis It must be emphasized that such an investment is generally beyond the capacity of the poorest people of the world who would really be the target group for such a programme

The computation above is presented only to outline the dimensions of what is possible and desirable and to emphasize the fact that this is a target well within the reach of the global community However, it would not be possible to achieve success with any such global programme unless appropriate investments are mobilized through channels which would ensure the success of such an initiative Even more important than the investments themselves would be the creation or strengthening of institutions and infrastructure in these societies both at the national as well as the grassroots level In essence, local institutions may have to ensure the distribution of petroleum products as implied in the programme mentioned above Then, we are also confronted with a more difficult challenge, namely that of ensuring that those who receive this benefit are also able to pay for the fuel supplied This in the case of women, who are currently spending time in collection of fuelwood, could be attempted through an employment programme which has a commercial objective, and which, in essence, supplies fuel for work to monetize the transaction at the level of the user This, of course, is a difficult task to accomplish and would require a new dimension being added to development programmes at the grassroots level Its success would lie critically in a bottom upwards approach rather than a centralized effort which is conceptualized and controlled at the top What this implies in a real sense is the articulation and implementation of a new paradigm for economic development among the poorest communities of the world But nothing short of such an approach is likely to work This is not suggesting the adoption of a grand national plan of action But in the initial stages of such an effort, the implementation of a few pilot schemes could be established to become the nucleus of a much larger national effort

In discussing the problem of biomass energy used largely by rural populations in the Third World we have only covered the very basic requirements of energy for cooking and heating applications. Other major end-uses for which energy is largely deficient among the poorest masses of the world are in respect of lighting and motive power The conventional approach for lighting throughout the world is through investments in expansion of electric power grids often with heavy subsidies which are becoming financially unsustainable in several countries. Given the high subsidies which permit the continuation of low tariffs of electric power in rural areas, the acceptance of alternative energy devices based on renewable forms of energy become financially unattractive to the consumer Subsidies in rural electric supplies have, therefore, become a major barrier in the spread of renewable energy technologies in several parts of the world, where they are already becoming viable in economic terms Here again the absence of local institutions for managing energy supply and distribution and the predominance of large electric utilities whose traditional practices favour large grid expansion, would over time become a major constraint What applies to the distribution of fuels for cooking and the need for the development of local institutions applies with greater force to the case of renewable energy technology dissemination The development of local organizations and skills in rural areas for promoting the use of renewable energy sources is an important forerunner of development in these areas Wherever renewable energy projects have been executed in the past they have generally followed the approach of technologies being developed in the countries of the north or on a centralized basis and hardware being dumped in remote rural locations without the development of local infrastructure and expertise It is no surprise, therefore, that we find most of these projects resulting in abysmal failure India must chart a new path in technology development suitable for rural areas and in evolving institutional arrangements for implementing renewable energy projects at the rural level

We would like to conclude by mentioning an initiative that TERI has launched with support from the Rockefeller Foundation, New York and the International Academy of Environment, Geneva called the Leadership in Environment and Development (LEAD) Programme This programme promises to be of great value in producing a cadre of motivated, enlightened and well informed leaders of business, government, the media and other sectors, so that over the next 10 years or so, India would have people in senior decision making positions fully in tune with issues of sustainable development A brief write-up on the LEAD Programme in India is provided as an Appendix to this paper But much more needs to be done, and the task is so gigantic and the challenge so complex that ideas must flow in from round the globe for action in every corner of this planet In this regard, let me emphasize once again that capacity building is a global task, and no single society must feel at the present juncture of human civilization that the problem lies only on somebody else's doorstep. The first thing we

need to do as a nation is to develop the capacity to accept ideas from others if we are to proceed further

What is being suggested in the foregoing paragraphs is that a new complex needs to be established through effective networking between organizations and institutions outside the government, not excluding, of course, government organizations The GEF has a challenging role to play in addressing global environmental problems, but its tasks would be facilitated through the establishment of what might be seen as a sort of mini GEF with capabilities at the national and regional levels Addressing environmental problems, both global and local, requires the emergence and strengthening of institutions at the most decentralized level Because what is involved is a major change in the direction and tradition of development itself This cannot be achieved unless initiatives are undertaken almost on a massive scale, which requires energizing society at every level Admittedly, these are issues which have to be discussed and debated by developing countries, societies and governments themselves, but by focussing attention on them the GEF can fulfill a very useful purpose in creating the conditions for changes in the direction outlined

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ANNEXURE I

In this appendix we give the detailed mathematical structure of the LP model for computing the minimal incremental costs of an abatement program which ensures that the economy remains on the strategy mandated GHG emissions path and at the same time does not jeopardise its growth objective

Possible formulations of a national strategy to limit GHG emissions

A national strategy to limit GHG emissions may, in our judgement, take one of two forms It may specify for each country (or category of countries) a path of future aggregate GHG emissions over time Or, it may specify (perhaps for each defined sector, say steel making, in given categories of countries or each country) a time path of GHG intensities of output (i e, tonnes of GHG emitted per tonne of steel produced)

In the case of DCs, it is unlikely that any national strategy in the foreseeable future would provide for actual reductions in GHG emissions, since it is expected that GHG emission growth rates may be unchanged, or increase, as the economy grows and undergoes structural change biased towards energy intensive sectors The constraint may therefore be in the form of reduced future growth rates for these emissions, and may even require the aggregate GHG emissions to stabilise at some time in the future The adoption of benign technologies would, over time, facilitate this

Even in the absence of a national strategy, GHG intensity may also be expected to fall with time, because of autonomous technological change, which may induce energy efficiency The GHG constraint may require a further reduction in GHG intensity over time through increasing use of benign technologies in the economy generally, and in particular in energy intensive sectors

The LP Model

The elements of the LP model are

(1) A discrete set of techniques

$$\{i\} = \{1,2, \quad ,N\}$$

(2) A discrete set of time periods

$$\{t\} = \{1,2,t, \ldots\ldots,T\}$$

(3) GHG intensity of each technique (GHG emitted per unit of capacity, however defined e g, MW of electricity) g_i and without loss of generality (w l.o g) $g_i > g_{i+1}$ for all i; i e, the more benign techniques are numbered lower in the series and $g_i \geq \leq o$, i e techniques may be sources, sinks, or zero net emitters of GHG.

(4) Capacity installed in each technique at time t
Q_i^t, for all i

(5) Specific cost of a given change in technique at time t.

$$\mu_{ij}^t = \frac{MIC_{ij}^t}{Q_i^t} \qquad (A1)$$

where MIC_{ij}^t is the minimal incremental cost of a change from technique i to j at time t (see main text) These costs may be illustrated as shown in the adjacent figure, where

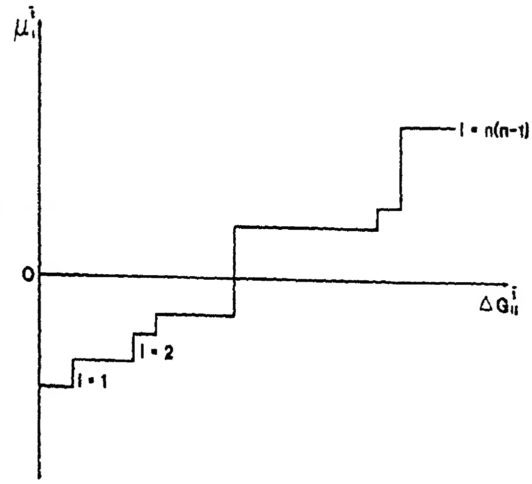
$$\Delta G_{ij}^t = (g_i - g_j)Q_i^t \qquad (A2)$$

i e, the abatement potential of the change in technique i to j at time t, and

$$\mu_l^t = \mu_{ij}^t \quad (l = (ixj)\backslash l) \qquad (A3)$$

and without loss of generality,

$$\mu_l^t < \mu_{l+1}^t$$



(6) An allowable set of technique changes

$$\{h \times k\} \subseteq \{i \times j\} \qquad (A4)$$
$$h > k, \; i > j$$

The definition of an allowable set may be such as to allow only changes in technique within given sectors Additionally, the allowable set may exclude abatement options which are repugnant to other policy considerations

(7) Time paths formulated under the national strategy, which may be, either
(i) Target GHG intensity of the economy.

$$\bar{g}_t = \frac{\sum_i g_i Q_i^t}{\sum_i Q_i^t} \qquad (A5)$$

or

(ii) Target aggregate emissions

$$\bar{G}_t = \sum_i g_i Q_i^t \qquad (A6)$$

The starting model assumption is that the strategy mandated path is adhered to at the current period t The LP model calculates the minimal costs of a program to ensure that the economy remains on the mandated path at time t + 1, given the economy's growth objectives These are specified as capacity levels in each sector at time t + 1 The planning objective (by assumption) is that the policy maker minimizes the net costs (maximizes net benefits) of the transition along the mandated path for each period

Suppose the economy at t moves to t + 1, along the mandated path Then the change in capacity of each technique j, is given by

$$\Delta Q_j^t = \sum_{i<j} q_{ij}^t - \sum_{k>j} q_{jk}^t + k_j^t \qquad (A7)$$

where

$\Sigma_{i<j}\, q_{ij}^t$ is the aggregate of switches to j from less benign techniques,

$\Sigma_{k>j}\, q_{jk}^t$ is the aggregate of switches from j to more benign techniques, and

k_j^t is the new capacity (retirement) in j at t

The incremental program cost is then given by

$$IPC^t = \sum_j \{ \sum_{i<j} a_{ij}^t \cdot \mu_{ij}^t \cdot q_{ij}^t + \sum_{k>j} a_{jk}^t \cdot \mu_{jk}^t \cdot q_{jk}^t \} \qquad (A8)$$

where a_{ij} etc is a logic driven parameter, such that

$a_{ij}^t = 1$ if $\mu_{ij}^t > o$,
$\quad = o$ otherwise

This definition of IPC^t includes the net costs of only those switches which have positive net cost

Now, let C_j^t be the specific net cost (positive net benefit) of new capacity in j, and r_j^t the specific net cost (positive net benefit) of retirement of j, at t in each case. The total cost of the program is then given by :

$$TC^t = \sum_j [(\sum_{k\neq j} a_{ij}^t \mu_{ij}^t q_{ij}^t + \sum_{k\neq j} a_{jk}^t \mu_{jk}^t q_{jk}^t) + f_j^t c_j^t k_j^t + h_j^t r_j^t k_j^t] \qquad (A9)$$

where f_j, h_j are logic driven parameters

$f_j^t = 1$ if $k_j^t > o$,
$= o$ otherwise

$h_j^t = o$ if $k_j^t > o$,
$= 1$ otherwise

(The total program cost nets out the net costs of technique switches having positive net benefits)

The growth constraints may be written as

$$\sum_{j\epsilon s} [Q_j^t + \Delta Q_j^t] \geq \bar{Q}_s^{t+1} \qquad (A10)$$

The right hand side is an exogenous specification of capacity in sector s, $\{s = 1, 2,\text{--}, n\}$, where s represents different sectors of the economy

The policy problem is then written as

Minimize TC^t
q_{ij}^t, q_{ik}^t, k^t

subject to

(1)

$$\sum_{j\epsilon s} [Q_j^t + \Delta Q_j^t] \geq \bar{Q}_s^{t+1}$$

(2) Either

$$\sum_i g_i Q_i^{t+1} - \bar{G}_{t+1} \leq o$$

(aggregate GHG constraint by national strategy),

or

$$\bar{g}^{t+1} \sum_i Q_i^{t+1} - \sum_i g_i Q_i^{t+1} \leq o$$

(economy's GHG intensity constraint by national strategy)

(3) $\{h x k\} \subseteq \{i x j\}$

(only allowable set of technique changes may be considered)

As with all LPs, only specific numerical solutions are possible, employing computer based algorithms The solution will yield the following sets $\{q_{ij}^{t}\}$, $\{q_{jk}^{t}\}$, $\{k_{j}^{t}\}$ The first two will enable the computation of the least cost IPC^{t}, using equation (A8) given above

ANNEXURE II

Bangladesh Country Paper

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The per capita commercial energy consumption in Bangladesh is as low as 56 kgoe Commercial energy accounts for only 30% of the energy consumed

According to this paper, the current CO_2 emissions from Bangladesh are only 4 24 million tonnes of carbon and hence an insignificant contribution to the global CO_2 emissions However, in the context of an extremely low efficiency of energy utilization, there exists considerable scope for streamlining consumption and thereby reducing CO_2 emissions Ten alternatives have been considered for limiting emissions from this country With the exception of one (afforestation), all alternatives aim to improve the energy efficiency of the economy (see Table 1) The package ranges from reduction in T&D losses and cogeneration to simple measures such as wider dissemination of improved cooking stoves and lighting devices From all the measures analyzed the savings in CO_2 emissions will be of the order of 75 MT-C by the year 2000 This potential may be a lower estimate, since the potential for reduction in T & D losses and lower CO_2 emissions thereof are based on generation levels of 1990

In the electricity sector, which suffers from a staggering 40% system loss, a 15% reduction of system loss over a 10 year period has been considered At a cost of US $ 82 million, 2 4 million tonnes of carbon emission can be prevented Similarly the industrial sector has a potential of saving 3 4 million tonnes of carbon emission using various technologies at an investment of US $ 108 million These technologies are economically viable projects, i e, a return on investment can be expected. The transport sector in Bangladesh consumes a large amount of commercial energy fairly inefficiently Of the various reasons behind it, poor road maintenance is the most significant A road maintenance program at a cost of US $ 110 million has been considered This results in a saving of 1 2 million tonnes of carbon.

The rural residential sector consumes a large amount of woody biomass resulting in net deforestation The combustion process (i e. cooking) of biomass in stoves presently being used is highly inefficient The distribution of improved stoves to rural households at a cost of US $

10 6 million can save approximately 2 3 million tonnes of carbon Similarly improved lamps can save 0 04 tonnes of carbon

The biggest potential of fixing carbon is afforded by afforestation At present 3 27 million acres of land remain deforested An afforestation program of this land will cost US $ 1255 million, which will fix approximately 65 4 million tonnes of carbon

This paper relies heavily on estimates made by various Government Committees regarding the investment requirements for implementing various measures It does not detail the assumptions for such investments for the power sector However details of phasing of investments, implied energy savings and valuation of the same are studied in depth for the industry sector

In conclusion, this paper highlights that although the level of energy consumption is low n Bangladesh, the gains afforded by energy conservation measures are large per se (i e , without focusing on CO_2 limitation criteria) In other words, benefits of adoption of a "no regrets" policy is amply exemplified by this study

Table 1 : Specific Cost of Technologies for Limiting CO_2 Emission

Technologies	Carbon Saved/Fixed MT	Investment Required M$	Specific Cost $/T
Electricity Sector			
T & D Loss	2 4	82 2	34 3
Industry Sector			
Housekeeping + Operation	1 4	10 78	7 7
Combustion Control	0 96	12 09	12 59
Simple Retrofit	0 07	1 1	15 77
Process Improvement	0 43	14 93	34 73
Cogeneration	0 55	92 809	168 74
Transport Sector			
Road Maintenance	1 18	110 0	93 0
Residential (rural)			
Unnata chulha	2 3	10 6	4 7
Unnata koopi	0 04	1 06	26 5
Afforestation	65 4	1255	19 2

Brazil Country Paper

Authors: **Jose Roberto Moreira (Secretariat of Science and Technology, Federal Government, Brasilia, Brazil)**

Alan D. Poole (Ecotropic, Rio de Janerio)

David Zylberztajn and Juliana Fries (Institute of Electrotechnology and Energy, University of Sao paulo, Sao Paulo)

The paper seeks to estimate the cost of avoiding CO_2 emissions in Brazil using new technologies for energy production and consumption Although it is widely recognised that the country's largest source of CO_2 emissions is deforestation, precise quantification of the emissions from this source is a controversial issue Therefore, the paper concentrates on emissions from fossil fuels and the possibilities for their reduction

The paper begins with an analysis of current CO_2 emissions by fuel type and consuming sector This is followed by a presentation of official baseline energy projections to the years 2000 and 2010 Two scenarios are described - a business-as-usual (BAU) scenario and an alternative energy scenario The BAU scenario assumes that the same political and economic constraints that exist today, persist in the energy sector, including the price policy The alternative energy scenario takes account of increased energy conservation, more efficient overall use of energy resources, the development of new institutional conditions to enhance efficiency and competition as well as more opportunities for private enterprise participation, and changes in the energy consumption profile to allow for greater use of alternative sources of energy (principally renewables)

The main bulk of the paper is concerned with an analysis of technical changes to reduce CO_2 emissions in the future Twenty two such changes are considered, dealing primarily with energy end-use in the residential, industrial, commercial, electricity generation and transport sectors On the energy supply side, the possibility of ethanol as a fuel to replace gasoline has been examined For each technology, the potential, CO_2 emissions reduction and costs are quantified The Brazil country paper goes beyond investment costs and considers O&M and fuels costs, as also the value of energy savings Cost differences between the initial investments for the new and in use technologies, and between the operational costs, including electricity and fuel saved are quantified A social discount rate of 12% has been used A cost curve is developed on the basis of this analysis and this is presented below in figure 1

Costs are found to be negative for 15 of the 22 technologies investigated This is a consequence of the fact that much conservation can be achieved at costs lower than those of energy supply. In these cases, CO_2 reduction simply becomes another reason to promote energy conservation. The most economically advantageous reduction in CO_2 emissions occurs through the use of better, already available technologies for lighting in the commercial sector Some CO_2 reduction measures seem to be quite expensive such as highway recuperation and metros However, a more detailed examination of all costs and benefits associated with each measure (including other economic and social benefits) may drastically change the net cost attributed to CO_2 reduction

The paper ends with a discussion of some very broad elements of a policy to significantly reduce the rate of deforestation and its associated costs It is argued that any strategy to achieve a large sustainable decrease in the deforestation rate must go beyond the police enforcement of forest land-use legislation Efforts should be made at creating an economy that is dynamically less predatory in its use of forest, land and water resources Measures suggested include the development of alternative economic activities in both deforested and forested areas, as well as the zoning of land-use

Figure 1 Cost curve for CO_2 emission reduction options in Brazil

China Country Paper

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Prof. Wei Zhihong

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The per capita commercial energy consumption in China is 0 6 toe, which is about one third of the world average Apart from commercial energy, a large quantity of biomass energy is still consumed to satisfy the demand in rural areas Biomass energy comprises 24% of total energy consumption nationwide and 75% of energy consumption in rural households

Since the energy intensity of the Chinese economy was 0 98 kgoe/US$ (at 1980 prices) in 1990, which was around 3 5 times that of the developed nations in early 1980s, there exists considerable scope for energy conservation and CO_2 reduction from the macro-economy point of view. To support this view, this study paper analyzes the existing potential and projects scenarios to the year 2000 of energy consumption and CO_2 emission. And finally, the cost of CO_2 saved or fixed by various technologies, are estimated according to the cost of capital investment, operation & maintenance, and fuels

Improvement of energy utilization efficiency, replacement of carbon fuels by non-carbon fuels, and afforestation are the major strategies which have been analyzed

Power generation sector (which consumes 280-300 Mt of coal each year), industrial boilers and kilns (which consuming 290-330 Mtoe of energy a year) and the household sector (which needs 100 Mtoe of commercial energy supply a year), are the biggest energy consumers, in which potentials for energy efficiency improvement exist In particular, this paper indicates that power generation efficiency can be raised from the current average level 30 7% to 37-38% by using advanced technologies of PFB or IGCC Heat efficiency of boilers and kilns can be upgraded from 55% to 65% and 25% to 30% respectively This can be achieved through technical innovation Cooking efficiency in urban households can be increased from 22% to 50% by gasification, and rural cooking efficiency from 10% to 20% by using coal-saving stoves Since the absolute energy consumption is very high in these sectors, efficiency improvement will result in a high energy savings and hence emphasis should be laid here

The paper further highlights that since the cost of using renewable energy such as solar, wind, geothermal is quite high hydropower and nuclear energy will be the major non-carbon fuels used in the near future It is expected that hydropower capacity will develop from 40 GW in 1990 to 80 GW in China by 2000, which accounts for 20% of the total exploitable hydropower resources Nuclear power capacity will be 6 GW in 2000

There are bright prospects for afforestation About 16-17% of the land area can be afforested by the end of this century The present share is 13% If this target could be realized, 690 million tons of carbon would be assimilated and no CO_2 emission would result from net deforestation

The specific cost of reducing CO_2 emission for selected technologies and measures are calculated and listed in the table below in a ascending order for comparison Preliminary results show that adoption of coal-saving stoves in rural households has the lowest specific cost, and this explains the recent thrust of policy on enabling 90% of rural households to use this kind of efficiency-improved stove by 2000 And, generally speaking innovation on existing equipments will have comparatively lower specific cost Finally, the fairly reasonable specific cost of both hydropower and nuclear power make them quite competitive

Table : Strategies for limiting CO_2 emissions (upto the year 2000)

Option	Potential	Total Cost (in US$)	Life time (years)	Cumulative CO_2 reduction during life time (million T-C)	Specific cost of CO_2 reduction (US $/T-C)	Specific cost of CO_2 reduction (US $/T-C)
Coal-saving stove	64 MH	1 5/H	10	305	0 3	9
Retrofit of existing boilers	0 2 million	5700	10	160	5	19
Pressured Fluidized Bed	1 5 GW	150/KW	30	9 5	12	19
Retrofit of existing kilns	46,000	65000	8	92 5	19	35
Hydropower	40 GW	1010/KW	50	1900	20	18 4
Nuclear power	6 GW	1185/KW	30	284	24	15
Solar heaters	1 9 M m^2	115/m^2	15	8	25	21
Afforesta-tion	34 Mha	370/ha		690	30	26 3
Combining cycle	1 0 GW	290/KW	30	5 2	30	37
Wind generation	48 MW	1270/KW	20	1 5	42	39
Solar P V.	9 3 MW	815/KW	20	1 5	49	45
Urban gasifica-tion	49 MH	475/H	30	360	50	42 3
Solar cooker	60,000	50	10	0 05	68	64

Note 1 US$ is at 1990 price

2 MH means million households

3 Total cost includes investment cost, and operation & maintenance and fuel cost which have been discounted to the start year using a 10% social discount rate

4 Specific cost of CO_2 reduction in 5th column covers the costs of capital investment, operation & maintenance, and fuels, but that in 6th column only covers capital investment cost

India Country Paper

Authors: Ajay Mathur, Sujata Gupta and Neha Khanna

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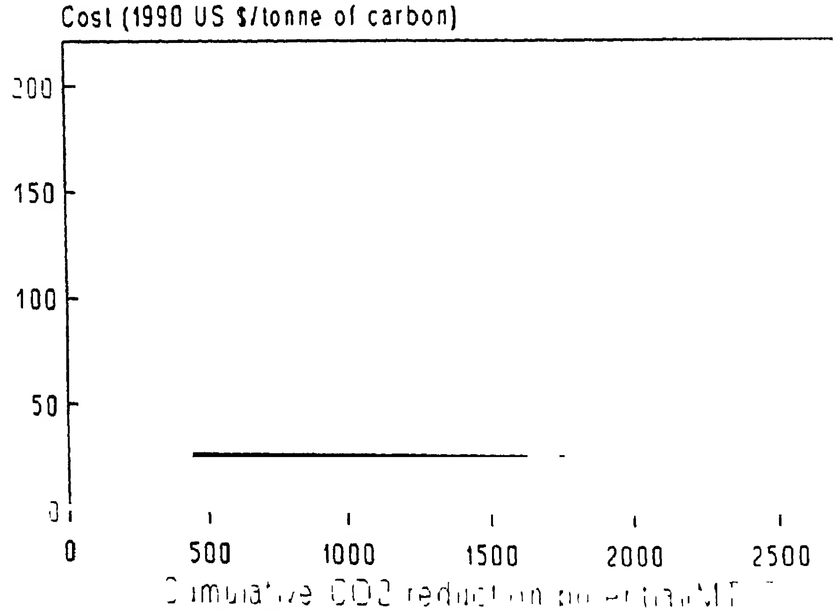
The India Country Paper examines strategies for reducing primary energy consumption, principally of CO_2 producing fuels, without reducing end-use services A bottom-up analysis has been employed The working principal underlying the paper is to identify CO_2 abatement options implementable by the year 2000, the extent to which these options can be realistically adopted, the associated investment costs and the reduction in CO_2 emissions made possible over the lifetime of each option A brief analysis of the constraints to the implementation of the identified options and the institutional mechanisms suitable for channelling the incremental inputs is also undertaken The various CO_2 abatement options are then ranked in ascending order of specific investment costs of CO_2 reduction The cost curve is developed by plotting the cumulative potential for reduction in CO_2 emissions on the horizontal axis and the corresponding specific costs in ascending order on the vertical axis The area under the curve thus gives the total quantum of investments required to implement the options

Three broad strategies have been investigated These are increase in energy utilization efficiency in the electricity, industrial, transport, agricultural and domestic sectors, fuel switching (which includes a larger deployment of renewable energy technologies), and afforestation The largest potential for reducing CO_2 emissions is through afforestation (i e a total of 1540 million tonnes of carbon over 35 years) at a total investment cost of 42 04 billion US $ Coal washing emerges as the cheapest option, in terms of the specific investment cost The energy efficiency related options have specific investment costs ranging from US$ 3/T carbon (in the case of coal washing) to US $ 221/T carbon (in the case of enhanced rail freight movement) The figure overleaf depicts the cost curve generated on the basis of the findings

Cost curve for energy related carbon dioxide emission reduction options



Emission reduction potential is the total carbon saved over the life of the option (in million tonnes of C)

Iran Country Paper

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Total energy consumption in Iran in 1989, was 68 24 Million Tonnes Oil Equivalent (MTOE) Considering the enormous gas and oil resources, about 95% of consumed energy was provided by liquid and gas fossil fuels The total CO_2 emission from fossil fuels was about 39 2 million tonnes of carbon Coal is only used in industry (steel, smelting, and sugar producing industries) and is not used for power generation Electricity generation in Iran is either from hydroelectric power or by burning petroleum products A study of the sectoral consumption of electricity (1989) indicates that the domestic and commercial sectors are the highest consumers, accounting for 28 7 per cent of the total electricity consumed

Estimation of emissions of CO_2 from sectors indicates that fossil fuel burning (oil and natural gas consumption) and deforestation contribute significantly A sectorwise analysis of CO_2 Emission in Iran (1989) points towards a high percentage of these emissions coming from the domestic and commercial sectors Sharing the international concern over global climate change, and having suffered directly from the pollution, in the Persian Gulf region caused by the burning of Kuwaiti oil wells, Iran has already undertaken serious steps to curb CO_2 emissions (i e in using oil and natural gas which are cleaner fuels in power generation) and is also examining the potential for further limitation in the other major energy consuming sectors as well as afforestation

In this paper, after looking at the energy consumption in Iran, present day CO_2 emissions estimation, then projection of energy supply and demand for year 2000 are touched upon At the end, technologies to curb CO_2 emission and preliminary estimates of cost of abatement measures are studied The future potential and the investment cost for some of the limitation options has been briefly deliberated upon The options of hydropower and nuclear power have been examined based on projected plans through the year 2000

Japan Country Paper

Author: Naoki Matsuo
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Japan is credited with having achieved one of the highest levels of energy conservation among the developed countries. In order to limit CO_2 emissions in the future, she must develop and induce extremely advanced technology Information regarding these technologies is scarce and uncertain. Thus, the Japan country paper is different from the others in the study in that it presents only some cost examples

The paper begins with a review of past trends of energy demand and CO_2 emissions in Japan This is followed by a projected energy supply/ demand outlook for the years 2000 and 2010 using a simulation model developed by the IEE First, a standard scenario (in which no special supplementary measures are taken) is constructed and corresponding CO_2 emissions are estimated The major assumptions in this scenario include a slowly declining rate of economic growth (in real terms) and industrial restructuring to increase the value added to products and to service-oriented industries Account is also taken of the delay in securing sites for the construction of nuclear power plants due to the anti-nuclear movement Next, in a simulation exercise aimed at the stabilization of CO_2 emissions, analyses are made on six scenarios These scenarios call for the stabilization of CO_2 emissions at the level of those in fiscal year 1989 by 2010 and 2000, and for the stabilization of CO_2 emissions at the level of those in 2000 (in the standard case) in and after 2000 A combination of basic assumptions such as improvements in energy consumption efficiency, the extent of introduction of new energy sources, the level of economic activity and energy prices are varied It should be noted that (i) the case of high energy prices is assumed to have the same effect as that of introducing a tax (eg a carbon tax) aimed at restricting CO_2 emissions, and (ii) in introducing new energy sources, two models are assumed - a model for new energy cost and a model for the introduction of new energy sources The former is used to estimate the cost of new energy sources and to determine the year in which the new energy sources become competitive vis-a-vis the existing ones The market share for each new energy source in each year and volumes of new energy sources to be introduced are estimated by the latter model by multiplying those shares by total energy demand. Assumptions are varied in the energy cost model For each scenario, magnitudes of GNP losses (or slow-down in economic growth rate, in real terms, are estimated).

The simulation exercise reveals that stabilization of CO_2 emissions at the level of 2000, in and after 2000, accompanied by energy conservation and promotion of nuclear power development, seems to be the most feasible scenario since it entails the least reduction in the rate of growth of GNP

The next section of the paper introduces the "Action Program to Arrest Global Warming" formulated by the Government of Japan This programme aims at the stabilization of total as well as per capita CO_2 emissions in the year 2000 and beyond at the 1990 levels To achieve these targets, the programme recommends a combination of restructuring the economy and lifestyles

The fourth section talks of energy conservation and new energy technologies in Japan This includes a factor analysis of CO_2 emissions in Japan and other countries, an overview of the Sunshine and Moonlight Projects instituted by the Japanese Government to promote the development of efficient technologies for CO_2 reductions, and a list of energy conservation technologies for the future This is important since the factor analysis reveals that energy conservation has played the most important role in reducing CO_2 emissions in Japan

Examples of estimated costs to save CO_2 emissions from the residential/commercial, industrial and energy conservation sectors of Japan are presented next Bottom-up method is applied to obtain these estimates This section draws extensively from papers written by other authors

The paper ends with a discussion of the role of technologies and Japan's international cooperation in the abatement of global CO_2 emissions It is argued that there is a substantial potential for CO_2 emission reduction if other developed and developing countries improve their energy efficiency to the level attained by Japan Thus, it is felt that Japan is capable of making a significant contribution through the transfer of modern technology This section also includes estimates of capital costs needed to realise the above mentioned potential in Eastern Europe and developing countries (viz China, India, Brazil, South Korea) Two approaches are used to obtain the cost estimates - a micro-economic and a macro-economic one Results obtained from these two approaches differ from each other by as much as three times These differences arise due to differences in the calculational methods

The Japan country paper also contains an appendix entailing a critique of the Energy-Environment Policy of the Japanese Government It is argued that the targets set by the Ministry of International Trade and Industry in its latest long-term energy supply-demand outlook are extremely optimistic in terms of both technology and costs, and that there are wide gaps between the goals and reality

South Korea Country Paper

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Korea's gross natural product has maintained an average growth rate of 8 6% per annum in real terms, in the last two decades The GNP per capita has also increased from $ 288 in 1971 to $ 6,569 in 1989 in nominal terms Resulting from the fast economic growth, total energy consumption has increased sharply given that total primary energy consumption in 1990 was 93,193 thousand TOE as compared to that in 1980 which was 43,911 thousand TOE

Being poorly endowed with domestic energy resources (which are limited to anthracite, firewood and hydropower) Korea has had to import all other energy sources from abroad Its import bill for energy amounted to $ 10 92 billion in 1990 The import dependence ratio of energy consumption is very high and approached 85 5% in 1989 (including nuclear) and is likely to continue to rise

Examination of energy demand by sector for 1990 shows that industry accounts for the highest share of 48 2% followed by residential and commercial sector which accounted for 29 2 per cent

At present the industrial sector is responsible for a major share (36 2%) of current CO_2 emissions This is closely followed by the residential/commercial sector which accounts for about 27 3% of the estimated current CO_2 emissions The transportation sector has the third largest share of CO_2 emissions (1990) which is 18 4% of the total CO_2 emissions from all sectors According to the authors, it is expected that both electricity generation and transport will outpace the other sectors including the residential and commercial sectors in terms of CO_2 emissions in the future This is anticipated due to the anticipated rapid growth in vehicle population The increased contribution of the former to future CO_2 emissions can be attributed to the long term plan of building 23 new bituminous coal fired power plants

CO_2 emissions by fuel type is mainly from petroleum which was 53%, followed by 44% for coal The proportionate shares within coal are expected to alter from the present (anthracite 18% (1990) to 6% in (2000) and Bituminous presently 26% to 32% in 2000 The high share of petroleum is likely to continue increasing to 56% in 2000

Some of the measures adopted by the Korean Government to reduce GHG levels include reinforcement of energy conservation, improvement of oil refinery technology, and preparation of the environmental act For instance in the residential and commercial sector, energy

conservation has been strengthened by reinforcing thermal insulation standards and regulations on constructing new houses as well as on commercial and public buildings

Thailand Country Paper

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Thailand's gross domestic product in 1989 has grown by 12 2% in real terms over the previous year, accompanied by a growth of 15 9% in final energy consumption Of the total energy consumed in 1989, 47 2% was imported This high level of imports, has led to a domestic policy which encourages use of domestic energy resources, which are natural gas, oil, lignite and biomass Both firewood and hydropower (domestic resources) use are unlikely to grow, due to depleted forest reserves,
the 'forest close down policy' and public opposition to construction of dams

Emission of CO_2 from fossil fuel (coal oil and natural gas) was estimated to be 26 million tonnes of carbon or 68% of total carbon emissions Use of charcoal and fuel wood resulted in 12 million tonnes of carbon or 32% of total carbon emission

The paper argues that it is evident that use of fossil fuels like lignite and crude oil has been on the increase Hence strategies for limiting GHGs must concentrate on conservation, increased efficiency of production and utilization and increased usage of renewable energy resources

A likely option is increasing energy utilisation efficiency in the transport sector which is a major consumer (38 9%) of the total energy consumption Lowered energy consumption would limit GHG emissions as well as decrease energy imports In the transport sector, CUERUI (Chulalongkorn University Energy Research Institute) has recommended measures like a mass transit system and maintenance of road surface among other measures In the sector of power generation, which is greatly dependent on fossil fuels (89%), co-generation could be considered a feasible option in the near future There is limited scope for electricity generation from nuclear, hydro and solar sources, in the near future, according to the authors of the paper

Development of renewable energy technologies has not received adequate attention from the government, apart from the high cost factor involved in its development There is a limited use of such technologies in the rural areas Despite this, in some parts of Thailand prototypes of solar, wind, small hydro and geothermal stations are already functional

As of the present, Thailand has a 25-28% forest cover The authors have calculated that a figure of 0 0345 million square kilometres of forest cover would be required to balance CO_2 emissions from fossil fuel use in the country

The potential for maximum energy saving has been estimated, for the industrial, commercial, residential and public sector It has been estimated that no energy savings are possible in sectors other than those mentioned above without adoption of more advanced technology or significantly large investments The potential for total energy savings is 16% of the total energy consumption

As far as CO_2 abatement technologies are concerned, two measures, viz afforestation and energy generation from agricultural waste have been considered. At a cost ranging from 643 7 million to 748 8 million per year (based on a 5 year rotation) Thailand could prevent 11 9 million tonnes of carbon from being emitted per year

A study conducted by CUERI and NEA (National Electricity Agency) on Electricity from rice husk as well as from agricultural waste indicates the existing potential in the rural areas to change from wood, charcoal or electricity use to electricity from agricultural waste based gasifiers The cost of replacing all the electricity used by the industrial sector will be 640 million US $, leading to a decrease of 1 103 million tonnes CO_2 per year This measure would be beneficial in reducing GHG emissions resulting from electricity generation using fossil fuels such as lignite which is currently being used for this purpose

Energy-economy Linkages
- Use of Modelling Approaches?

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Integrated Energy Planning in India: A Modeling Approach

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The economic planning process in India can broadly be broken up into two steps the building up of Five Year Plans and the specification of Annual Plans Several planning models were used to arrive at a balanced allocation of resources for attaining the objectives and targets of growth and social welfare postulated in each Five Year Plan.

The basic modeling structure has evolved over the last thirty-five years to comprise a core model and seven major submodels, viz agriculture, industry, consumption, poverty, export and import, financial resources, demography and employment The core model consists of (i) a macroeconomic model encompassing a number of national income and expenditure identities, (ii) an input-output model which determines the output levels needed to satisfy various sectoral demands—demand for public and private consumption, demand for investment (public and private), demand for exports and demand for intermediate goods and, (iii) an investment model which determines, with the help of (i) and (ii) investment requirements in the last year of the Five Year Plan (Planning Commission, 1981)

The submodels are used to ensure feasibility of the output levels determined by the input-output model. The main role of these submodels is to estimate the supply potential of the different sectors vis-a-vis (i) the investment allocation made in the different plans, (ii) the rate of completion of existing projects and programs, and (iii) the utilization of the capacity available in the course of the implementation of the plan.

THE ROLE OF ENERGY IN PLANNING

An examination of the input-output model structure, which forms the bulk of the core model, reveals the highly aggregated nature of the

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planning process for the energy sector in India The entire energy sector is covered in five subsectors of the fifty-sector input-output table for the Seventh Five Year Plan (Planning Commission, 1986) These are. (i) coal and lignite, (ii) crude oil and natural gas, (iii) petroleum products, (iv) coke, bitumen, and miscellaneous petroleum products, and finally, (v) electricity, coal gas, and water supply. Even here, the last two sectors are an aggregation of energy and nonenergy sectors. The above level of aggregation of the energy sectors contradicts the otherwise important role of energy in the economy. Energy as a whole has been accounting for an increasingly large share of investment in the economy and currently stands at close to 30 percent of total public investment

THE ROLE OF ENERGY IN ECONOMIC DEVELOPMENT

Over the last two decades the energy sector has played a dominant role in setting the trend for overall economic development. The roots of industrial stagnation, agricultural production losses, transportation bottlenecks, inflation, etc experienced in recent years can, to a large extent, be traced back to the energy sector—its failures in production, distribution, quality, prices, etc

An overview of India's energy sector is provided in Figure 1, which shows the trends in energy consumption[1] from 1950–51 and 1985–86 The average annual rate of increase in energy consumption during the 1950s and 1960s was slightly over 7 percent This is relatively high compared to the 3 9 percent annual growth rate of real GNP over the fifteen-year period This is of particular concern because of the large amounts of foreign exchange required for these imports, which consist largely of crude oil and petroleum products

Table 1 provides a computation of the cost of energy consumed in the economy In current prices, the contribution of the energy sector to the GNP has gone up from 6 percent in 1970–71 to 14 percent in 1985–86 At the same time, the cost of importing crude oil and petroleum producs has increased from 9 percent of export earnings in 1970–71 to 41 percent in 1985–86, down from a peak of 78 percent in 1980–81 following the second oil price shock.

1 The vast coal reserves of India prompted the use of the coal replacement index in all national energy studies since the early 1960s as this facilitated the quantification of coal required to replace other fuels for a given task The principal advantage of this index is that it contains information about the true substitutability of fuels in different processes Its disadvantages are that it requires significant additional information about fuel substitutionally in all energy-using activities of the economy and constant revisions of the substitutability factors since relative efficiencies change over time

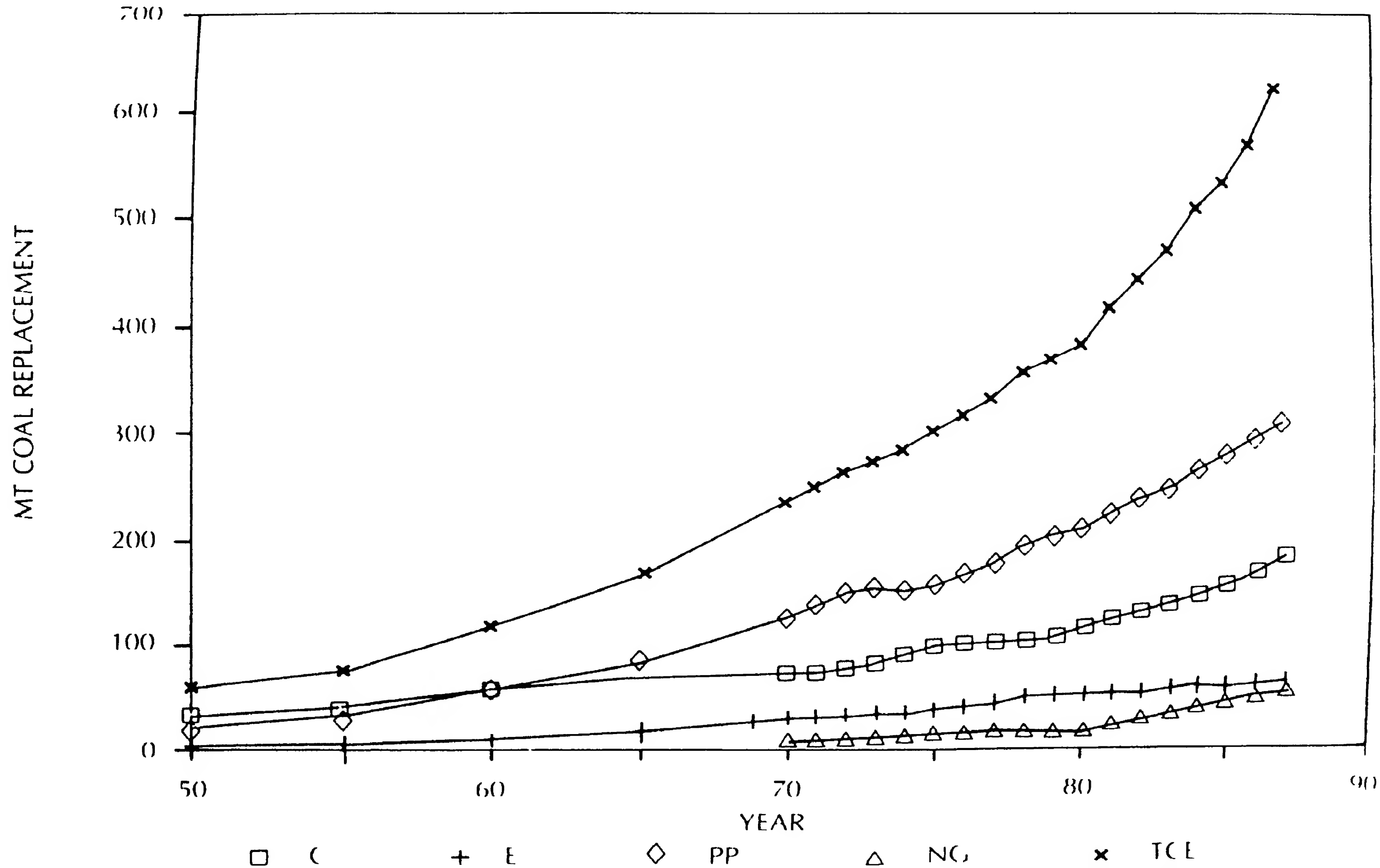

Figure 1. Trends in Commercial Energy Consumption, 1950–51 to 1987–88 (MTCR).

Table 1. Cost of Commercial Energy Consumption to Economy (Rs. crores)

	1970–71	*1975–76*	*1980–81*	*1981–82*	*1982–83*	*1983–84*	*1984–85*	*1985–86*	*Annual increase between 1970–71 and 1975–86 (%)*
GNP at current prices	39,979	74 089	127 812	147,385	164,059	192,266	212,208	233,000	12 5
Value of output of energy as % of GNP	6	7	10	11	12	12	12	14	
Import of Crude Oil and Petroleum Products (Gross)									
1 Quantity (million tonnes)	13	16	24	20	22	20	20	19	2 6
2 Value (Rs crores)	137	1 256	5 266	5,190	5,598	4,812	5 345	4,700	26 6
Value as % of total export earnings	9	31	78	67	63	49	45	41	

Source Centre for Monitoring Indian Economy *Basic Statistics Relating to the Indian Economy* Vol 1 All India August 1986

Immediately prior to that time (1978–79), the share of oil in commercial[2] energy consumption was greatest in transportation (84 percent), followed by households (71 percent) and agriculture (63 percent) It was much smaller in industry (8 percent) By 1984–85, the share of oil in transportation and households had increased further (to 93 percent and 83 percent), while those in agriculture and industry had fallen (53 percent and 7 percent).

The government's immediate response to the challenge posed by the first increase in oil prices was to undertake a series of policy-oriented subsector reviews It pursued a two-pronged strategy, including efforts to increase domestic production (so as to permit a reduction in imports) and to constrain the overall growth of energy consumption During the fiscal year 1973–74, the Government established a system of allocation of petroleum products based on the previous year's consumption in each industrial unit, allowing for an annual reduction in each case The result was that the share of petroleum products in total energy consumed in the industrial sector decreased from 20 8 percent in 1972–73 to 17 4 percent in 1975–76 In the absence of such physical restrictions, the effect on consumption would have been insignificant within a regime of administered prices (and therefore low price elaticities) In addition, oil product prices were maintained generally above international price levels except for diesel and kerosene prices, which have remained lower till very recently

The Government also decided to implement efforts aimed at replacing heavy fuel oil by coal wherever feasible As part of this policy, wholesale prices of coal between 1973 and 1983 were allowed to increase roughly fivefold and those of fuel oil eightfold As a consequence, the share of fuel cost in total input cost of industries went up significantly (see Table 2)

Taking into account the recent increase in energy prices, the share of energy in total costs of the industrial sector could currently be estimated at around 10 percent According to official estimates it is possible to save Rs 31 billion per annum (approximately $3.1 billion at February 1983 exchange rate) through investment in energy conservation schemes in industry, transport, and agriculture These savings would have accounted for nearly 60 percent of India's import bill of crude oil and petroleum products in 1984–85, which was around $5.3 billion.

FUTURE ENERGY PROSPECTS

A recent study carried out by the Advisory Board on Energy[3] projected that if during the next 20 years the economy grows at the rate of

2. Data for traditional energy usage are too incomplete for inclusion in the comparisons.
3. "Towards a Perspective on Energy Demand and Supply in India in 2004–05," May 1985

Table 2. Share of Fuel Cost in Total Input Cost of Major Industries: 1970–71 and 1981–82 (Rs. crores)

Industry group	*% Share of Fuel Cost to Total Input Cost* 1970–71	1981–82
Food products	1 9	3 2
Beverages & tobacco products	1 5	3 5
Cotton textiles	5 8	9 6
Jute textiles	4 5	9 4
Wooden furniture & fixtures	2 9	4 3
Paper & paper products including printing and allied industries	9 4	13 8
Chemical & chemical products	7 6	12 0
Cement & other mineral non-metallic products	25 1	27 9
Basic ferrous & non-ferrous metals & alloys	13 3	14 7
Metal products	3 8	4 2
Transport equipment	3 9	4 8
All Industries	5 5	9 2

Source Centre for Monitoring Indian Economy, *Basic Statistics Relating to the Indian Economy* Vol 1 All India August 1986

5 percent per annum, the current level of energy demand may multiply 3 5 times, from 565 Million Tons of Coal Replacement (MTCR) in 1982–83 to 1985 MTCR in 2004–05 The study estimates the demand for crude oil at 94 to 123 million tons (MT) by 2004–05 Assuming the country is able to produce 50 MT of crude oil by 2004–05, this would still entail imports of 44 to 73 MT of crude oil Given the current proven reserves of 495 million tons and the production level of 30 million tons in 1985, India's presently known recoverable reserves would be totally exhausted within sixteen and one-half years, i e , by the year 2000, unless additional recoverable reserves are found in the meantime India is making substantial efforts to develop and tap renewable energy production in the country and to improve the efficiency of use of biomass (utilized largely for cooking in rural areas), but all this would not make a significant dent in the demand for conventional energy, namely oil, coal, and power

THE NEED FOR INTEGRATED ENERGY PLANNING

Until now the planning process has dealt with energy in a somewhat fragmented manner Different departments and ministries deal with coal, oil,

and natural gas, power, nonconventional forms of energy, and atomic energy Coordination across different forms is generally brought about by the Planning Commission through the formulation and implementation of the country's Five-Year Plans, but thus far these plans have been dominated by a supply orientation, without adequate emphasis on demand management In 1983 the Government set up a high-powered Advisory Board on Energy to provide new directions to the country's energy policy, and its recommendations are gradually being implemented by the various ministries and the Planning Commission

To reverse the inadequate treatment of energy in the National Plan, several obvious requirements need to be treated as an integral part of the broad planning framework Briefly, these include

1 A reduction in the rate of growth of oil consumption leading, preferably to a decline in the quantity of oil consumed and imported.
2 Enhanced development and use of the country's substantial hydro power potential
3 Improved conductivity and efficiency of supply in the energy sector. (An analysis of selected energy intensive industries has revealed that close to 25 percent of their electricity requirements are met by costly captive generation units)
4 A massive program of forestation to increase availability of firewood and charcoal
5 Exploring the possibility of using solar and other renewable forms of energy

The impact of these and other strategies can be evaluated most comprehensively—both individually and collectively—with the help of an energy-economy model that takes into account the complex interactions and substitutions that are possible in the entire economy.

THE TERI ENERGY ECONOMY SIMULATION AND EVALUATION (TEESE) MODEL

The TEESE model attempts to capture these complex energy-economy interrelationships by adopting a methodology similar in many respects to that developed in the Brookhaven Energy Economy Assessment Model (BEEAM). The three component submodels of the TEESE model are: (i) a reference energy system, (ii) an input-output model, and (iii) a linear programming model. These submodels are closely interlinked. The relevance of the general approach lies in the fact that this model is fully compatible with the Indian Planning Commission's input-output model, which also forms one of the basic building blocks of the TEESE model.

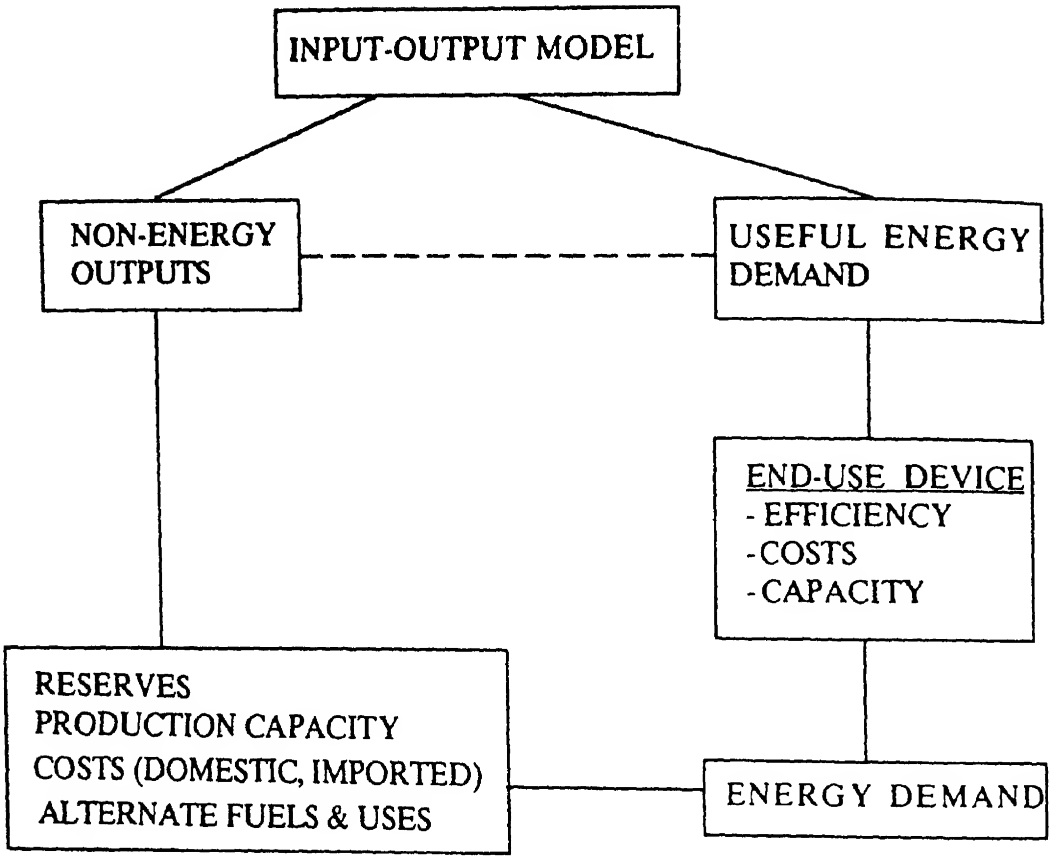

Figure 2. Main linkages in the TEESE model.

The underlying assumption behind the model structure is that useful energy or energy services for specific energy consuming sectors are being demanded for the service that they provide. For example, the demand for energy by households is measured in terms of demand for cooking energy, space heating, lighting, etc.

Figure 2 brings about the major factors that underlie the solution to the model The Reference Energy System (RES) and the Input-Output (I/O) Model both feed into the linear programming part of the TEESE model, with the I/O model determining the end-use energy requirements relating to a given level of economic activity, which in turn is derived from the final demands vector developed by the Planning Commission. The RES forms the balance equations in the Linear Programming (LP) problem relating end-use energy demands to different forms of energy supply

The gross outputs of the nonenergy sectors are determined with the help of the I/O model, which forms one part of the constraint set in the LP problem This approach is somewhat different from the iterative approach suggested in the BEEAM model; as opposed to this approach we have derived the magnitude of the useful energy for final consumption directly on the basis of several survey results for different income classes of the population The outputs of the non-energy sectors determines the demand

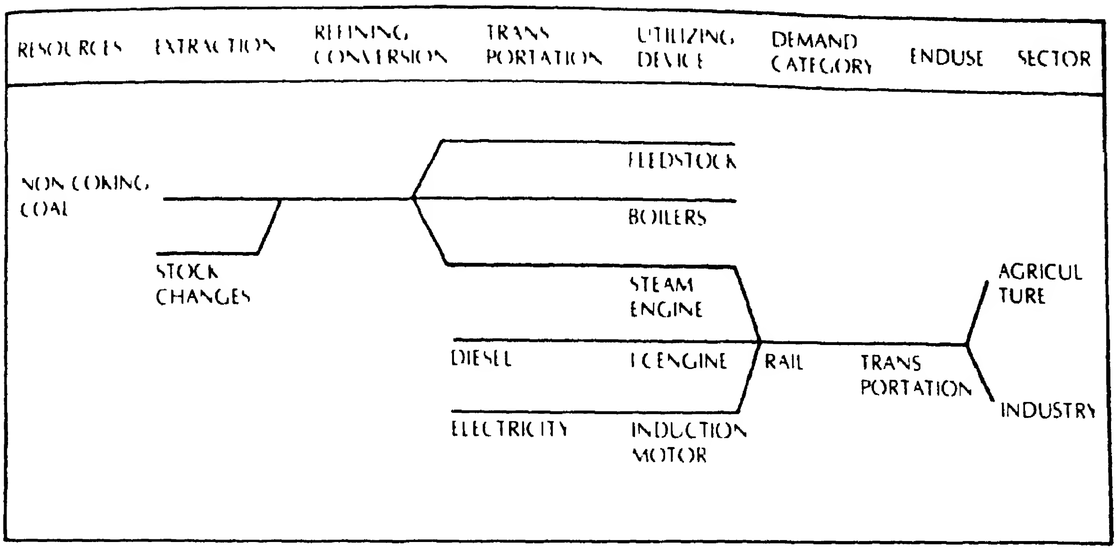

Figure 3. Partial reference energy system.

for energy services, which in turn would have an impact on the demand for fuels and their availability for providing other services

The relationship between the outputs of the nonenergy sectors (e g agriculture and industry) and the demand for useful energy/energy services (e g. freight transportation) is also estimated from a part of the Input-Output model, which feeds into the LP as constraints (This relationship is graphically explained by the Partial Reference Energy System shown in Figure 3.) The LP problem then determines the share of different fuels (e g , coal, electricity, HSD, gasoline, ATF, etc.) consumed by various end-use devices (trucks, steam locomotives, diesel locomotives, electric locomotives, etc.) while meeting a particular demand for useful energy/energy service (freight transportation —TKMS) It takes into account the following factors

1 Efficiencies of the different end-use devices
2 Capacities of the end-use devices for providing useful energy/energy service
3 Costs of the end-use devices
4 Availability of different fuel types
5. Economics of alternative uses
6. Costs of producing/importing various energy forms

Demand for electricity is allocated to the various forms of generating capacity available by taking into account a representative linearized Load Duration Curve and the availability of different types of plants for base, intermediate and peak load generation.

The model structure allows for the following uses of the model:

1. Study of substitution possibilities for fuels and end-use services and their impact on the economy as a whole
2. Projecting energy demands and indicating an optimal mix of energy to

3. Analysis of the impact of various assumptions involving technology, capacity, income levels, etc. on energy demand/supply as well as on economic aggregates.
4. Assessing the conservation potential and a ranking of priority areas.
5. Cost-benefit analysis of supply enhancement versus demand management.
6. Allocation of resources among competing sectors

The LP formulation as it exists comprises 241 variables and 154 constraints. The model is set up on an IBM-PC/AT and uses a software package known as LP83. The data files have been organized in LOTUS format, and the entire solution time for the model is three minutes

ILLUSTRATIVE RESULTS FROM THE TEESE MODEL

After checking for the consistency of the model by running the Input-Output submodel, the optimization model was run for the base year 1984–85 and for the future year 1989–90. Table 3 presents results from these two runs and compares them with actuals for 1984–85 and official projections for 1989–90. Since the model solution is an optimal least-cost solution, the results do not obviously match reality Several runs of the model were made to test it for its sensitivity to changes in the values of different parameters These runs proved valuable in providing an understanding of several policy issues in which optimal conditions may not be attainable Some possible explanations are offered where the results are significantly at variance with actuals.

Estimated electricity demand in 1984–85, according to the model results, turned out to be marginally (2 5 percent) lower than actual electricity consumption, while existing hydro-, thermal-, nuclear-, and gas-based capacities all were fully utilized No diesel-based capacity was being utilized according to the model output, probably because of high marginal costs of importing diesel into the country Electricity consumption by the agricultural sector, according to each output, was lower both in actual physical units and in percentage terms, the model found it more economical to use diesel directly in pumpsets rather than to have it converted into electricity by the industrial captive power generation sets and then permit larger electricity usage for irrigation pumping. The share of the domestic sector was significantly higher than what was actually consumed as it was not possible for us to take into account the loss in consumption due to deteriorating quality (frequent power cuts and so on)[4]

4 For details on electric sector equations please see Meier (1984), pp 239 240

Table 3. Optimization Model Results

	1984–85		1989–90	
	Actuals	Model results	VIIth Plan	Model results
Elec Demand (TWH)	136 32	132 96	223	216
Industry	80 89 (59 34%)	77 13 (58%)	139 3	128(59 26)
Transport	3 33 (2 45%)	2 65 (2%)	–	4 53 (2 1)
Domestic	15 63 (11 46%)	19 39 (14 6%)	26 88	33 86 (15 7)
Agriculture	22 06 (16 18%)	20 34 (15 3%)	32 42	29 02 (13 44)
Coal Demand (MT)	136 16	145 37 + 6 8*	226	241 + 17*
Iron & Steel	22 66	23 25	41 1	34 9
Power Generation	60 36	63 18	120	128 5
Railways	9 46	9 4	8 0	9 89
Petroleum Product Consumption (MT)	38 4	31 43	52 67	49 66
HSD Consumption	13 5	13 99	–	20 74
Transport	11 77	9 7	–	11 9
Agriculture		2 9	–	6 77
Share of Middle Distillates (%)	57 8	77	59	71 65
Crude Oil Imports (MT)	13 64	12 9	14 4	16 0
HSD Imports (MT)	2 57	–	4 13	3 51
SKO Imports (MT)	2 61	4 19		6 89

*Middlings consumption

Estimated consumption of coal is larger than actual consumption as actual use was restricted by supply constraints In addition to the 145 million tons of coal being consumed, 6 8 million tons of middlings were produced and consumed in the power sector.

Estimated petroleum product consumption turned out to be much lower than actual consumption in 1984–85, due to an underrepresentation of light diesel oil and fuel oils. Demand for kerosene was estimated to be much greater than it was actually in 1984–85; LPG extracted from domestically produced natural gas was not accounted for, and the constraints on the availability of traditional forms of energy introduced in the model may have been unrealistic Estimated high-speed diesel consumption was slightly higher than the actual level in 1984–85, with the transportation and agricultural sectors accounting for a little more than the difference in the totals. The share of middle distillates was forecast too high at 77 percent, again due to the very high estimate for kerosene No diesel was imported into the system but estimated kerosene imports were too high by 60 percent

The model was also run for the year 1989–90, and the results from this run were compared with the projected energy demands/availabilities as given in the Seventh Five-Year Plan document (see Table 3). Electricity demand as estimated by the model was lower than the Plan's by about 3 percent. Industry accounted for almost 60 percent of the demand, the domestic sector for 15.7 percent, and agriculture for 13.44 percent. The high level of demand for electricity by the domestic sector is largely due to the demand for refrigeration, which was close to 56 percent of the domestic sector demand.

The demand for coal by the iron and steel industry was estimated at around 41 million tons of washed coal against the projected figure of 35 million tons of coking coal The demand for coal by the power sector, on the other hand, was estimated at 8 5 million tons above the Plan level Total coal consumption was estimated at 241 million tons, which included the production target of 226 million tons for 1989–90 plus stock depletion of 15 million tons Close to 7 million tons of coking coal needed to be imported to meet the demands of the iron and steel industry.

The model estimated petroleum product consumption lower than the Plan However, imports of crude oil were higher (16 million tons) and imports of middle distillates were very much higher (over 10 million tons against the Plan level of 4 3 million tons) The share of middle distillates, though lower than that in 1984–85, is still very high at 71 65 percent Assuming a rate of growth of 15 percent in tractor population over the five years from 1984–85 to 1989–90, it was found that all tractor capacity would be utilized Consumption would be 2 14 million tons of diesel, while the residual demand for cattle for land preparation purposes would be 10 million head Irrigation water demand from underground sources was estimated at 440 billion cu m by the terminal year of the Seventh Plan The demand for diesel for irrigation purposes was estimated at 4.63 million tons

Finally, it was found to be cheaper to import fertilizers than to produce them domestically if no minimum utilization factors are specified This is because of the differential between the domestic cost of the production of naphtha and its export price Also, it was found to be cheaper to import finished products directly rather than to import crude oil and refine it domestically, in spite of existing refinery capacity, because of the current weak world market for petroleum products

The TEESE model has been set up for the terminal years of the eighth and ninth Five-Year Plan periods, that is, 1994–95 and 1999–2000, and outputs are being fed in regularly to the Advisory Board on Energy and other agencies of the Government of India to provide a basis for an ongoing policy process and for establishing directions for the future There is a continuing process of intensive interaction in this effort between the Government and TERI, the builders of this model

CONCLUSIONS

The above results are illustrative, and the model has been undergoing a continuous process of expansion and refinement

The outputs from the TEESE Model and the implications derived from several runs produced indicate some clear directions for energy policy in India. These directions to not represent a major departure from recommendations put forward in several reports of Committees set up by the Government However, for the first time a policy tool is now available through which a quantitative evaluation of the costs of deviating from these policy prescriptions and the benefits from implementing them can be accurately assessed The policy prescriptions derived from the outputs of the Model are

1 Containing the demand for middle distillates would result in a high level of net benefits for the Indian economy
2. A substantial shift from diesel to electric traction in railway transport is highly desirable At the same time, a shift from diesel to electrically driven pumpsets for irrigation would be desirable in the long run But in the short run, given the shortage of electric power capacity, the use of diesel for irrigation is preferable to its use in captive power generation in the industrial sector
3 An increase in power availability through investments in transmission and distribution and increased plant load factors is cost-effective
4 A reduction in the consumption of kerosene through increased supply of LPG extracted from natural gas is economically efficient.
5 A shift in the use of natural gas to power generation as against an almost exclusive allocation of natural gas supplies for fertilizer and petrochemicals production would be economically desirable
6 Purely on the basis of costs, there appears to be a strong case for imports of fertilizers as against indigenous production. Since fertilizer use involves a critical sector of the Indian economy, namely, agriculture, perhaps a security premium should be added to the cost of imports for evaluating the import-or-manufacture option.
7 Given the rapid rate of depletion of forests and the large demand for fuelwood energy, investments in afforestation schemes properly implemented would appear economically efficient.
8 Based on current costs, there is a strong case for the use of renewable forms of energy for end uses such as irrigation, water heating, lighting in rural areas, etc

As is necessary with any model used for policy analysis, the TEESE model is being constantly refined to provide more relevant and accurate outputs However, given that this model has been adopted by the Advisory Board on

Energy and is being actively used for its work in articulating a medium term energy policy for India makes this model more than an academic exercise. The experience gained with the TEESE model in India is, therefore, a useful example of how national institutions can work in partnership with national governments to develop a quantitative tool for energy policy analysis

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The Economics of Climate Change: A Review of Modelling Experience

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Technology Driven (Bottom Upwards) Models

A classification between bottom up and top down models is to a large extent artificial. In essence, both types of models, if they are truly representative of economic realities, rest on a set of assumptions that are germane to decision-making in the energy environment field. The distinction, if any, between two types of models arises out of the extent of disaggregation that is incorporated in each, the time horizon for solutions and the manner in which technology variables are specified. In the case of the bottom upward models this is done far more explicitly and in greater disaggregation than in the case of top downwards models. Consequently, bottom upwards models are generally based on a clearer depiction of specific technologies and processes than top downwards models which aggregate such processes into broad economic variables.

In the ultimate analysis, models of all kinds are based on the specification and estimation of production functions. The pioneering work of Gary Becker has established that consumption processes, including those in the household, are also essentially based on production functions, wherein the household or consumer combines a range of inputs, including consumer goods and his or her own time as inputs to produce services that he or she demands. This view is compatible with the interpretation that energy, for instance, is consumed not as energy or fuel *per se* but as an input for producing space heating, lighting, heat for cooking etc. It is, therefore, understandable that energy models developed during the seventies and eighties explicitly looked at the flows and transformation processes by which specific energy forms were converted into specific energy services. Of course, a number of these models took an instant view of the entire energy system, and therefore, did not specifically include the deployment and use of factors of production other than energy. In other words, inputs like capital, labour and raw materials were held constant or treated as variables outside the system that was depicted in the model. This did not actually create an artificial division between the family of process type models and those based on production functions either at the micro or the macro levels. A major step forward in the evolution of energy modelling was the various studies that were carried out using translog production functions which typically specified capital, labour, energy and raw materials as factors of production combined together by specific technologies resulting in the output of goods and services. Several of these models often disaggregated the factor energy into different forms including oil, coal, natural gas etc., which permitted the inclusion of substitution responses resulting from changes in factor

prices and costs.

In general, process flow models did not explicitly take into account technological change. Technology in such cases was embodied and specified in the nature of coefficients converting energy from one form into the other at various stages of the cycle. Coefficients also defined energy transportation and transmission as well as its output in the nature of energy services at the end of the cycle. Technological changes and their impacts were, therefore, assessed by introducing changes in the coefficients of conversion. In later models, facilities for bringing out changes in these coefficients were incorporated in the models themselves. A brief review of how these energy models have evolved is provided in the following section. This is essential for an understanding of current state-of-the-art in this genre of models, because environmental variables have been introduced and added in recent years to traditional energy models that were earlier employed only for assessing energy related choices.

This section provides a brief overview of the energy-economy-environment models that have been developed over the past two decades, driven by various objectives. These models have come a long way since the evolution of those which were constructed purely for the optimisation of national or sectoral energy systems. The earliest vintage of models have, over a period of time, been modified to include social and environmental considerations. Most of the earlier efforts concentrated on static one period models, which allowed only for short term planning. These were subsequently refined to incorporate the dynamic interactions of the energy sector and the economy through time phasing. Models can be grouped in several ways, depending on the questions that they aim to answer and the manner in which they are constructed. Among a number of relevant distinctions between types of models, the top-down vs. bottom-up classification can be seen as one often labelled as macroeconomic and the latter as engineering or process models. In general, most of the engineering or process models suffer from a serious drawback with inadequate accounting of the link between the energy system and other economic and social systems. In the bottom-up approach itself, we could classify three distinct types of models. These are partial forecasting or spreadsheet models, integrated energy system simulation models and energy system optimization models.

As against the partial forecasting models, in the integrated energy system simulation models, the demand sectors are, to a large extent, disaggregated with

respect to specific industrial sub-sectors or processes, the basic aim of this being that of making consistent scenario projections for defining the sector's long term behaviour. This allows for a detailed modelling of the alternatives for technical innovation, fuel switching etc. The disaggregation into specific technologies for various industrial sub-sectors makes it possible to carry out a detailed analysis of the abatement options through different characteristics of energy technologies. Despite some very powerful features of models in this category, there are some associated limitations as well. Firstly, the scenario simulation approach does not indicate whether a system optimum has been achieved. Optimization can be carried out only through repeated simulation runs, which could prove to be both time-consuming and expensive. Secondly, a high level of disaggregation would require as great a detail in data, which is not only difficult to obtain, particularly from a developing country's perspective, but which would also require a thorough knowledge of the model system for appropriate interpretation of results.

Energy system optimisation models form an important category of complex energy models that use linear programming to determine the optimal mix of energy supply and demand. The system is optimised using minimised discounted costs over a long-term period as the objective function and a number of infrastructural parameters as constraints.

A brief outline of some of these models developed for the energy sector is given below.

Brookhaven Energy System Optimization Model (BESOM)

BESOM is a linear programming model that evaluates energy technologies and policies quantitatively within a systems framework. The LP format in the model lends itself to investigation of different scenarios by optimizing different objective functions. The model also allows examination of a range of inter-fuel substitution possibilities. It follows the basic approach of multicriteria analysis through a direct computation combined with a parametric analysis that generates efficient solutions. Here, competing objectives like cost minimisation, environmental impacts reduction and increased use of renewables are selected.

The model is initially run for one objective and then by constraining this objective at the minimum, the contribution of the second parameter is optimised. Efficient points in the system are generated as we move from one to another. If

the values arising out of these runs are plotted, we obtain a set of efficient* solutions For selected environmental values, the corresponding environmental index is set as an equality constraint, and the model is then solved to minimize cost for decreasing amounts of renewables. This fresh set of runs generates the iso-environmental curves E_1, E_2, and E_3 (as in Fig. 1). Corresponding to each of these curves, there exists a minimum cost solution. Connecting these points gives the dashed curve S, which represents the set of efficient solutions, for which cost is more important than renewables, subject to an implied environmental constraint. This provides a measure of improvement that can be attained by making new technology options available.

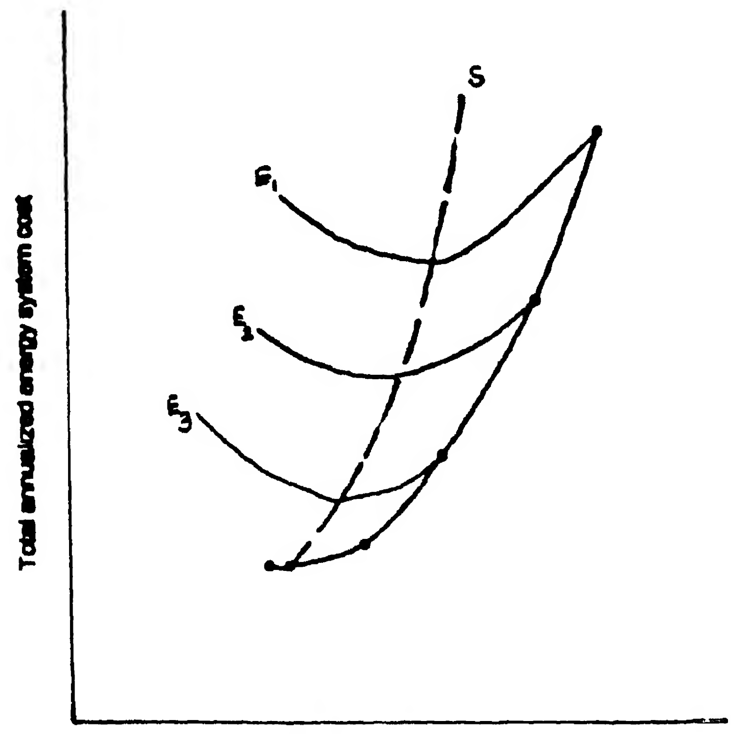

FIG. 1. Multi-objective analysis of cost, renewables, and environment.

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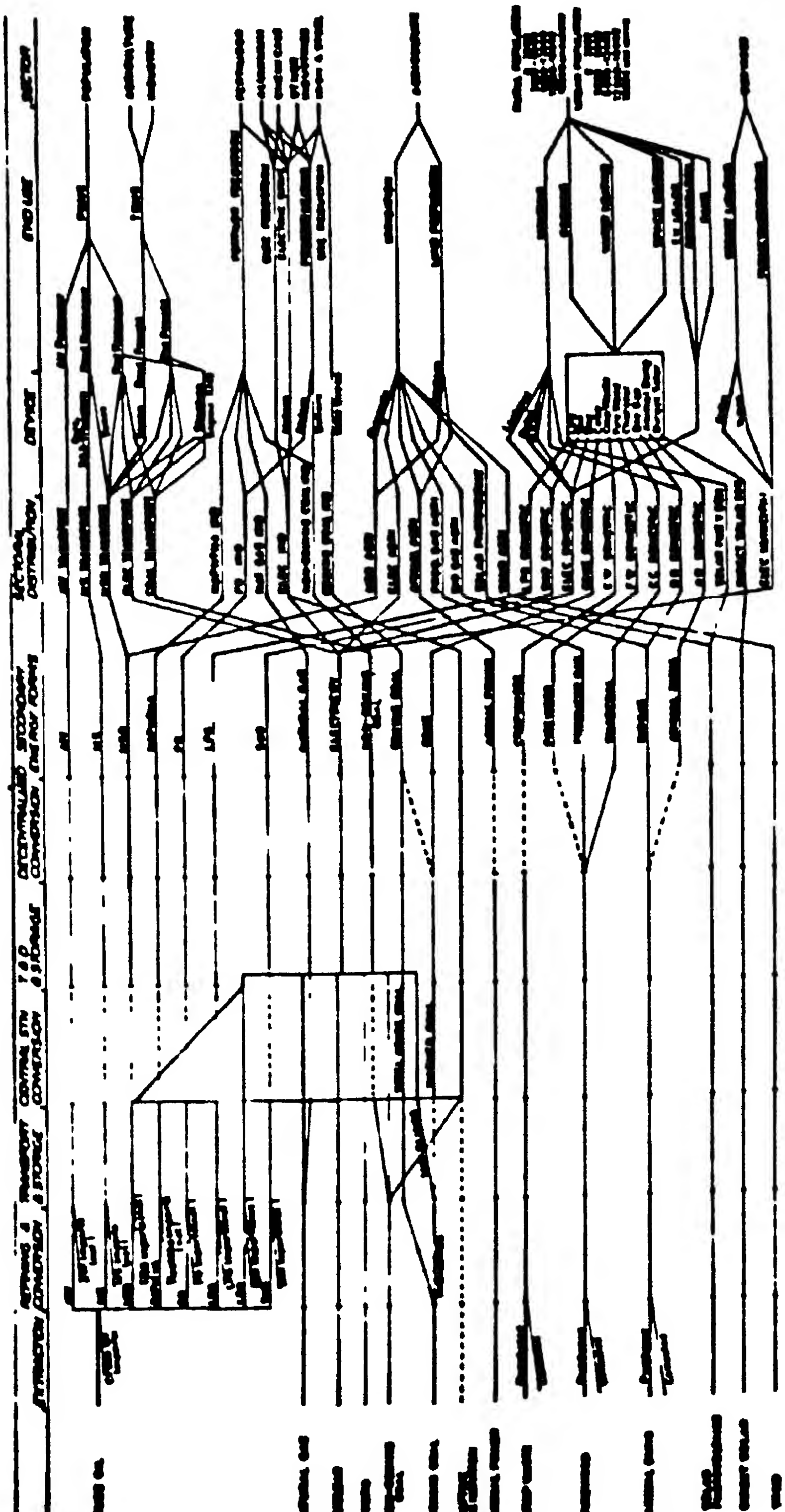
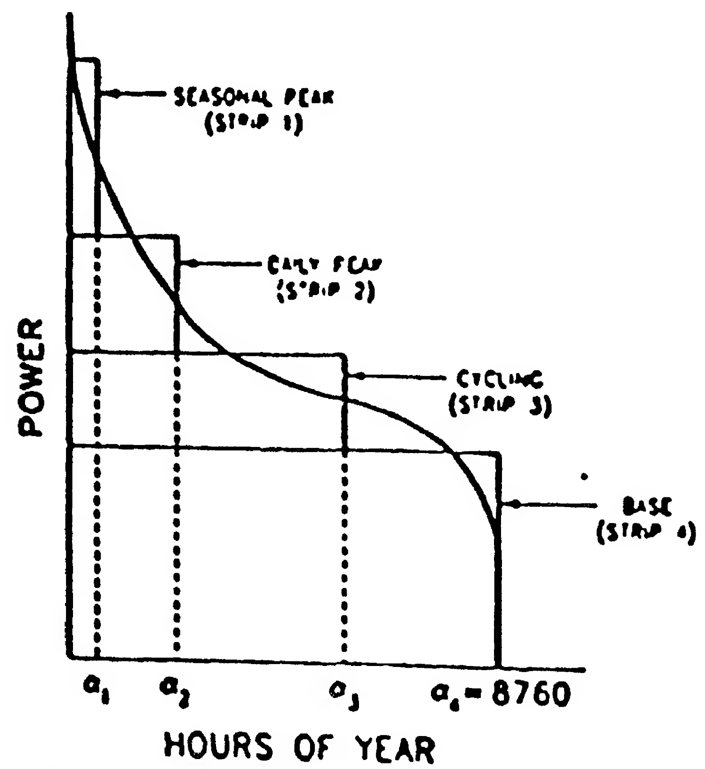
* a point in multicriteria is efficient if one criteria cannot be improved without at least one other being worsened

Fig..2 An illustration of the Reference Energy System



One of the important features of the model is its comprehensive technology structure that encompasses alternative energy resources as also the entire demand sector. Structured around a Reference Energy System (RES), BESOM concentrates on technical, economic and environmental characteristics of energy conversion, transmission or utilization processes comprising the entire energy system. Apart from these, it incorporates load duration characteristics and it is applicable to national as well as regional planning.



Four-step approximation of the annual load-duration curve.

The model has the flexibility of being used either in an optimization mode or in a simulation mode. While the former gives optimal supply-demand configurations to exogenously specified constraints, the latter allows analysis of total system costs and environmental impacts. Environmental emissions and costs are associated with each of the processes along the trajectory, from primary resource supply to end-use demand. The total impacts for each activity are calculated and summed up along each point in the energy systems network. The simulation module works by constraining the model to duplicate the desired

Brookhaven Time-Stepped Energy System Optimisation Model (TESOM)

A variant of the BESOM, this model was conceived of and developed to provide an extensive automated simulation capability and as an alternative tool to assist in the study of energy supply-demand distribution systems. Here, the optimal levels of the decision variables for any specific time step or period are computed exclusively from the optimal levels established for the previous time periods and the assumptions for the lifetimes, retirement rates, energy related economic and technological factors.

Mathematically, the time stepped model is formulated as a sequence of expanded LP problems. The solutions derived from the first year are incorporated as additional constraints to be met in the next time period.
The model contains a number of features designed to smooth the intertemporal transitions indicated by the sequence of solutions and regulated by interperiod control equations. Among these are the mechanism for pricing and adjusting the availabilities of old stocks and an improved market penetration algorithm. For each type of energy conversion device, TESOM adjusts the market penetration rates through time. By imposing small lower bounds for each year, marginal values are generated for each of the technologies, in the penetration algorithm. Those device types which remain at the lower bound are dropped from the stock, to keep the problem size manageable. If there is a tie in the ranking for two of the technologies, then new capacity installed for each follows ratios of capacity expansion potential implied by the penetration rates. One could thus conclude that TESOM controls the market penetration for each vintage stock, by fixing the availability of old stock and restricting the fuel consumption by new stock to the adjusted incremental upper bound.

TESOM performs a sequence of single period optimizations based on past decisions, present requirements, and expectations about future price, supply and demand trends. Energy demands are satisfied in accordance with supply availability, technology penetration attainable for the period and the selected objective function. The optimization procedure is repeated till solutions to all the timesteps are determined.

The model structure in TESOM also compares each technology with other

supply-demand system, thus computing the costs and other quantifiable impacts of emission levels. The advantage of the simulation module is that it can be used to rank the technologies for their attractiveness from the standpoint of resulting marginal benefits in conjunction with assumed prices.

BESOM could be used to assess the incursion of environmental control. The methodology followed allows one to compute the shadow price for a reduction in the amount of pollutant released. As data on the harmful effects of pollutants become known, it would be possible to weigh these against the increase in cost for mitigating these emissions. The use of shadow prices, in this case would thus help in selecting among alternative policies for control on environmental degradation.

The major limitations of the model are its linear representation of energy technologies, particularly the end-use energy saving measures, which can only describe constant returns to scale. Furthermore, most attractive technologies are, in general implemented to their full extent first, followed by the next one in the ranking. This, however, is not a very realistic situation as new technologies are introduced gradually and in parallel. Also, the growth rates supplied for the extraction and supply of basic fuels is based upon the previous period's output and not on new capital investments. A breakup of the capital investments in these industries could furnish a more accurate path.

Brookhaven Dynamic Energy System Optimization Model (DESOM) is an extension of the BESOM. As BESOM is static, it is designed to generate optimal fuel mixes within single period constraints. The dynamic version extends this capability to multiperiod mixes. This facilitates time-phased flows of resource use and creation and phasing out of energy capital. The aim of developing a dynamic energy system model is to determine whether or not future resource scarcity is adequately reflected in current market prices and usage. Analysis of the impact of resource scarcity on the rate of usage is determined on the basis of the finite bounds of resource availability and total recoverable reserves. The solution of the model gives the optimal usage pattern for each time period.

relevant technologies for each period against the total energy system needs. This helps in generating an attractiveness indicator which is used to adjust the new capacity potential. The system is designed in such a way that this indicator plays a less significant function if the length between successive periods is sufficiently long.

This model differs from other models of the same type, in a number of ways. An important implication of the latter is that all system shocks such as oil embargoes or other disruptions are foreseen and the patterns of energy use are altered in anticipation of these changes. Since TESOM is not designed to anticipate these disruptions, it lacks the ability to smooth the effects of these shocks until after they have occurred.

MARKet ALlocation (MARKAL) model

This is a demand driven, time-phased LP model that is designed to analyze the energy supply distribution systems over a given time horizon by optimizing a network of energy flows (RES). Each link in this network of energy flows is characterised by one or more typical technologies available for the model to choose from. The model generates the best energy system network for each time period by selecting a set of distinctive technologies by optimizing over the entire time horizon. The net result of minimizing total discounted cost over all time periods is that the model behaves as though it has full knowledge of the past and present for decisions made at each time period. Thus, the model draws upon existing facilities most efficiently to plan ahead.

MARKAL is driven by a set of useful demands specified exogenously for each time period by end-use category. Interestingly, future end-use energy conservation is included through a dummy fuel to account for potential fuel savings. Thus, it allows selection of conservation technologies to be included in the model and provides a convenient way to reiterate the role of conservation in each time period.

MARKAL captures the strengths of DESOM and smoothens the demand behaviour for market penetration of technologies. Unlike TESOM, all supply availabilities, demanded quantities, technologies etc are assumed to be known for the entire time horizon. Specifically designed to study the effects of new technologies in meeting expected future energy demands, the model can also study

the sensitivity of the evolution of an energy system to initial date of availability of technologies and permitted capacity growth rates. In that, MARKAL represents a significant advance for dynamic linear programming energy models. One of the most important features is that inputs to the model are automated as the required data are directly generated by a database management system. Having a comprehensive sectoral representation, the model also incorporates seasonal variations in availability (for instance, the case of unavailability of hydroelectric power in winters).

One of the key limitations of the model emanates from the available input data. The model uses a supply curve based on lifetime costs and utilization rates for evaluating technologies. As the lifetime cost itself is dependent on variations in prices and utilization rates, the section of the supply curve treated by the model as flat, would actually have an upward slope. This is likely to result in overprediction of the amount of a given energy efficient technology being applied to meet a level of energy demand or carbon constraint. Another limiting factor arises out of the time lag between decision and implementation associated with policies for the first time-step. Since energy capital decisions in the recent past and immediate future cannot be made to adapt to the model, the simulation runs would systematically overestimate feasible reductions and underestimate costs that would be actually achieved at future dates. The model should, therefore, be refined to allow simulation of optimal investment decisions to begin at a specified future year. Further limitation is induced by lack of regional detail. For instance, in the case of the power sector, demand in one region could be met by supply throughout the country. As costs of many supply options may be region specific, the model is likely to overestimate the utilization levels and underestimate the costs for some trajectories. Regionalisation would also have made the model more powerful for the evaluation of environmental control.

TERI Energy Economy Simulation and Evaluation (TEESE) Model

The TEESE model is formulated and developed around the approach of the family of models characterised by the Brookhaven Energy Economy Assessment Model (BEEAM). After a comprehensive survey of all the existing energy models, the BEEAM approach to modelling was adopted for its compatibility with the planning models already in use in India. The input-output framework used by the Planning

Commission in India for carrying out its plan formulation exercises forms the basis of the TEESE model. The model provides a long run bottom-up planning for the energy sector at the national level. The model comprises three main parts: a Reference Energy System (RES); an Input-Output (I/O) model; and a Linear Programming (LP) framework. The model provides a mathematical representation of the energy flows in the economy by accounting for conversion and T&D losses. The objective of the model is to derive a least cost supply strategy for different types of fuels to meet the estimated end-use wise demand for different energy services. The model draws up capacity expansion plans for fuels both at primary as well as secondary levels. This is done with due consideration to associated capital requirements and inter-fuel substitution possibilities. Furthermore, the model estimates CO_2 emissions and proposes a least cost CO_2 abatement strategy for the sector.

The major limitations of the TEESE model are due to the structure of the I/O matrix. Firstly, the level of disaggregation of sectors is restricted by the I/O sector classification. Also, as the I/O coefficients are in monetary units, the model does not capture the physical usage of energy forms. Secondly, for allowing inter-fuel substitution possibilities, the model ignores the gross output generated for the energy sectors through the I/O matrix, as these are fixed coefficients. Through the RES, the model estimates the optimum mix of the fuels. In doing so, the model does not account for the change in the gross output matrix as a consequence.

Modelling for decision-making related to climate change is essential to permit an assessment of the socio-economic aspects of possible impacts and mitigation of and adaptation to the climate change. To that extent models that are employed for this purpose must depict as accurately as possible the social and economic characteristics of systems that are likely to be influenced by climate change. At a disaggregated level these models, therefore, necessarily have to be local in coverage where it would be feasible to construct them and they would also have to be sectoral where decisions pertaining to specific sectors would have to be taken in respect of both mitigation and adaptation. It is important, therefore, to ensure that process type and technology driven models adequately reflect economic realities and faithfully depict behavioural variables and their interlinkages. In fact, the models that have been reviewed above do attempt this integration with some degree of rigour. The extent to which economic variables are included explicitly depends to a great extent on the time period that is embodied in these models. For instance, in various linear programming optimisation models, the time horizon is generally short, and therefore capacity and capital constraints are

included to account for rigidities that operate in some of these variables in the short run.

In the case of models that look at both mitigation and adaptation measures, there is some danger in transplanting short run optimisation models developed in the industrialised countries for applications in the developing countries. This would happen because the existence of well organised markets and institutions in the developed countries permit specific responses within short time periods that are not generally evident in the developing countries. In other words, mitigation and adaptation costs in the developing countries would, at the margin, require investments in the creation of infrastructure, institutional arrangements and, most importantly, specific skills which then may permit responses that are somewhat similar to those in the developed countries. The limited number of models that have been developed and utilised in the developing countries have generally ignored this aspect and have thereby understated the costs associated with specific mitigation and adaptation measures.

Technology changes, it must be pointed out, in such situations are not merely a case of a quick fix involving transfer of specific hardware, processes or knowhow from the North to the South, but inevitably involve the creation of appropriate infrastructure and skills as well as the ability to adapt and apply new technology under a set of conditions generally different from those obtained in the developed countries. If we accept this reality, then the choice of technology takes on a dimension which has generally been ignored in decision-making in the past, often with very unsatisfactory results. It would be optimal, therefore, to pursue an approach which explicitly relies on the choice or development of technologies that are not necessarily "sophisticated" but which can be directly introduced into specific situations in developing countries. At the same time we would have to identify a range of inputs and investments that would be necessary to create a suitable set of conditions for successful introduction of a power technology at the end of such a process rather than at the initial stage.

The Asian Energy Institute has carried out several studies estimating the costs of mitigation measures to limit greenhouse gas emissions in a number of countries in Asia, but these are essentially first cut estimates of direct investments required for specific actions and changes for reducing greenhouse gas emissions. The other elements of marginal costs related to capacity building in its widest sense have not been included in the studies. The next range of efforts

would necessarily have to concentrate on this type of analysis. But this would require indepth studies on existing institutions, infrastructure and regulatory arrangements and the measures that would be required to strengthen them. In essence, the optimisation process using quantitative models would have to come to grips with allocation of resources for capacity building measures in general, in conjunction with specific mitigation measures that are traditionally possible to include in these models. Such work needs to be pursued with urgency to provide full estimates of agreed full incremental costs, which are central to the implementation of the Climate Change Convention.

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International Negotiations on Climate Change: Developing Countries's Perspective

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The Climate Issue: Environmental and Socio-Political Considerations*

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Introduction:

The issue of anthropogenic Climate Change has, in just a few years, assumed *Prima-donna* status among global environmental concerns Indeed, it perhaps now ranks next in importance only to security and the international trading system among multilateral policy concerns.

Policy analysis typically involves uncertainties in facts and data, causal relationships, changes in exogenous conditions, and outcomes of policy options Nor can the policy analyst neglect ethical or value judgements, since ultimately their audience, who hopefully include policy makers, are concerned about the distributive consequences of policy actions, who wins and who loses The potential contribution of the policy analyst to policy debate is this first as regards analysis of positive aspects ("is" questions) he employs the scientific method, albeit with limitations imposed by the nature of the phenomenon under study, in predicting the range and likelihoods of policy consequences Second on normative aspects ("ought" questions) he employs formal ethical theory in prescribing courses of action

Consensus and the key uncertainties in Climate Change:

These general considerations hold rather forcefully in the Climate Change issue. While there is scientific consensus that if past growth trends of anthropogenic emissions of GHGs continue, over a period of several decades there will be changes in key climate parameters increase in average global temperature, alterations in the quantity and distribution of precipitation, cloud cover, soil moisture, and importantly, rise in mean sea level These changes may translate to impacts on natural vegetative cover, agricultural potential, public health impacts (in particular the range of vector borne diseases), submergence and salinization of low lying coastal regions, increased damage from tropical cyclones Some of these impacts, for example extension of the northern limits of important cereal crops, may be benefical, however, for the greater part they may be adverse In some instances, for example if there is significant reduction of precipitation in currently arid areas, or due to sea level rise in some small island territories, there is *tangible* risk of catastrophe

The question of whether the increased atmosphere concentrations of GHGs since pre-industrial times, which without dispute is owing to anthropogenic causes, has actually manifested in climate change cannot yet be definitely established (i e, within conventional limits of statistical confidence) While the earth has indeed undergone some warming on the average in the past several decades, this increase in average global temperature is still within the range of natural climate variability

Predictions of Climate Change and its impacts are shrouded in considerable uncertainty. The uncertainty arises, first, because future paths of economic growth over several decades cannot be predicted with much confidence, and accordingly, emissions of GHGs, their future atmospheric concentrations, and increase in radiative forcing are all uncertain. Second, the

climate system is extremely complex and yet imperfectly understood, so that even if detailed, accurate data, including future atmospheric concentrations of GHGs were available, it is still not possible to make detailed and accurate predictions of climate changes, including by means of General Circulation Models (GCMs) Third, ecosystems and social systems are also highly complex and imperfectly understood This means that it is not possible to accurately translate Climate Changes to impacts on ecosystems or patterns of human activity Reducing these uncertainties through research will take time, but the "precautionary principle", adopted in all the global environmental agreements at UNCED mandates that policy actions must be taken earlier, if policy makers seek to reduce at least the risk of catastrophic impacts

The normative dimensions of Climate Change fall in two broad categories First, that adverse or catastrophic impacts may befall particular societies quite without relation to their specific responsibility for causing the problem Second, that since anthropogenic emissions of GHGs are essentially involved in key economic activities energy supply and use, agriculture and animal husbandry, and land use changes, any global regulatory regime will, over time, involve significant real economic costs This is because several economic activities may need to be curtailed, and/or technological restructuring may be necessary The nature of the regulatory regime, including the time path of global GHGs emissions and allocations (explicit or implied) of emissions rights across countries over time, will determine the distribution of these costs, and possibly benefits, across societies and generations While the evaluation of the costs, benefits, and broader macroeconomic impacts of response strategies and regulatory regimes, including distributive aspects is a matter for positive policy analysis, choosing from the set of feasible options involves value judgements, including in particular, the question of rights to GHGs emissions Several DCs have supported allocations of future emissions rights on a per-capita basis, taking account of historical responsibility DCs scholars have shown that this principle has strong underpinning in formal ethical theory Alternative formulations which give positive weight to GDP would reward those who hear major responsibility for the problem and have already benefitted from higher level of emissions

Some Implications of the Framework Convention on Climate Change (FCCC):

The FCCC requires, among other things, that all participating states formulate, publish, and implement response strategies for abatement of emissions, enhancement of sinks, and adaptation to impacts Developing countries (DCs) are entitled to the "agreed full costs" of formulation and the "agreed full incremental costs" (AFICs) of implementation, through the *interim* financial mechanism (GEF) to which industrialized countries are required to make "new and additional" financial contributions While DCs have no explicit targets for stabilization or reduction of (net) emissions, a somewhat fuzzy norm of stabilization of emissions by year 2000 to 1990 levels has

been advocated for ICs This norm may be jointly implemented with other countries, including willing DCs

The concept of AFICs is a subject for further negotiation under the FCCC Typical formulations by ICs scholars have a microlevel, cost-benefit analytical flavour These approaches would tend to net out of "costs" the non-marketed benefits of response options accruing to the host country (e g reduction of regional air pollution), by imputing monetary values to such benefits by means of various techniques available in the environmental economics literature They would also largely neglect the plausible macroeconomic implications of national response strategies, reckoned over a range of parameters of policy interest, including, but not limited to GDP changes DCs scholars, on the other hand, emphasize that since the predominant (historical and current) responsibility for the problem lies with ICs, the concept of AFICs should incorporate positive incentives for DCs to enlist their participation In particular, the notion of AFICs should exclude local environmental and other non-marketed benefits, address broader macroeconomic implications of national response strategies, which in turn, may incorporate their economic and social development concerns, besides explicit climate change considerations

Some passion has been generated by the idea of ICs fulfilling their abatement commitments by involving DCs, i e under the "joint implementation" provision of the FCCC The fear expressed by some DCs scholars is that by this means the low cost abatement options in DCs may be exhausted early, and if in the future DCs are themselves burdened with explicit abatement responsibilities, they would encounter higher (marginal) abatement costs. To my mind, the danger is that policy makers in DCs may be temporally myopic, and accordingly give much greater weight to short-term gains to DCs from joint implementation, relative to the weight given to long-term costs of early exhaustion of low cost abatement options Accordingly, some joint implementation agreements may not be of long-term advantage to the concerned DCs

What are the plausible approaches to formulating a national response strategy for India? The specific local and regional climate change impacts are yet extremely uncertain, and the available knowledge is inadequate to identify appropriate adaptation options The efforts for the near term should be focussed on reducing these uncertainties through research There is increasing evidence that land use changes do not at present, in the net, contribute to the country's GHGs emissions However, the acceleration of afforestation programmes may significantly enhance the national sinks for carbon dioxide, with appreciable local non-marketed benefits, at modest marginal abatement costs Emissions of methane from the agriculture and animal husbandry sectors have been shown to be much lower than earlier supposed, and it is unlikely that in the near term, any significant changes in practices in this sector can be practicably undertaken

The major concern is, of course, the energy sector While energy conservation and efficiency programmes are a national policy priority even without considering their climate change related benefits, other energy related abatement options require careful evaluation The major domestic primary energy endowments are coal, hydropower, and nuclear fuel Since the capital investment involved in hydropower and nuclear energy per unit generating capacity, as well as gestations, are higher than for coal thermal plants, the major share of electricity supply investments is with the latter Major hydropower projects have also encountered strong organized opposition from the population likely to be displaced by the storage reservoirs Further, India has comprehensive manufacturing and R&D capabilities in conventional coal thermal plants, and Indian policy makers would be unlikely to accept transfers of more efficient coal based technologies involving lower levels of capabilities A major switch to natural gas based power generation would quickly run into domestic supply limitations, and increasing long-term, reliance on natural gas imports would be unacceptable to policy makers

India has had a strong policy commitment to renewables for several decades, which has been given even greater thrust in recent years Several RETs are technically mature, have been proven under Indian field conditions, and with elimination of distortions in pricing of conventional energy alternatives, may be disseminated at a rapid rate While one would count biogas generation, electric wind turbines, solar thermal applications, and micro/mini hydel among these, there are some others in which a major research effort, domestic and international, may, given India's needs and resource base, make appreciable impact Chief among there are biomass gasification and solar PV systems for rural electrification

Technology choice is not a straightforward matter of evaluating options on the basis of marginal costs of carbon dioxide reduction, for example, since diverse policy objectives may be involved These may include, as a sample, reliance on national natural resources, enhancement of national technological and institutional capabilities, minimizing local/regional environmental impacts, reducing exposure to volatile international energy markets, requirements of domestic capital, feasibility of domestic regulation, clarifying and minimizing possible catastrophic risks, besides others In analyzing policies for climate change, it is important that one is aware of these myriad linkages

Revenge of the Gods: Global Warming - Climate Change

Prodipto Ghosh

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Introduction :

Newton's third law: "Every action has a direct, opposite and equal reaction", may, as a metaphor, apply equally to man's relationship with nature, as it relates in the formal scientific sense to application of force on inanimate objects. An alternative characterization is that while man sought domination over nature in 5000 years of recorded history, in the last 50 years he has begun to realize that his welfare, indeed his very existence, is deeply intertwined with the integrity of natural cycles and systems.

Man is unique in Creation in many ways and one of these is his ability to devise new ways of using natural resources for his material well-being. So long as the requirements of his economic activities were small in relation to global stocks of critical natural resources, he could count, through intelligence, cooperation and labour, on improving his welfare. However his economic activities have increased at an exponential rate in the past several decades, and now his requirements have begun to press on the physical limits of nature. The result is the prospect of serious alterations in the earth's resource base and life support systems. The principal manifestations of these impacts are on global climate, the intricate web of forests, ecology and diversity of living beings, and increased transparency of the earth's atmospheric protective shield to harmful ultraviolet radiation. All these impacts are related, directly and indirectly with man's economic activities and with each other. They all have serious implications for his future well-being.

This article is concerned with Climate Change, also known as Global Warming (GW) or the anthropogenic (man-made) greenhouse effect. Let us begin with the last of these terms. In a greenhouse (i.e., a glass house used for growing plants in cold countries) solar heat radiation enters through the glass walls which are transparent to this type of (short wave-length) infrared radiation. The interior of the greenhouse warms up and in turn, radiates longer wave-length heat radiation. The glass walls are however less transparent to this second type of heat radiation, with the result that the interior of the greenhouse heats up to an

appreciable extent relative to its surroundings, before the incoming and outgoing heat radiation (which increases with rise in temperature of the interior) are in balance[1].

A similar natural process, with some atmospheric gases, principally water vapour, playing the role of glass walls of the greenhouse, is responsible for maintaining the earth at a salubrious +15°C on the average, compared to a dead frozen -19°C that would be the case otherwise. The natural greenhouse effect is, thus, essential for life on earth. Man's activities, (principally fossil fuel burning) has however, since the last century, raised the atmospheric concentrations of a number of gases (principally CO_2), which have greenhouse properties, with the result that signficant GW may occur in the next several decades. Since the global climate including rainfall, storms, wind patterns, ocean currents and sea level, is intimately related to the global heat flows and temperature patterns, there is a general expectation that the earth's climate may be significantly modified in the next 50 years. On the whole, the results would be adverse, and some impacts may be catastrophic. The principal greenhouse gases (GHGs) responsible for GW, together with their major sources and relative effectiveness in trapping heat (called "global warming potential" [GWP]) is given in Table 1. Fig. 1 is a simplified representation of the greenhouse effect. One should note, however, that this direct GWP is not the whole story. In particular, since CFCs destroy ozone (also a GHG) in the stratosphere, the reduced heat retention on account of ozone depletion may approximately equal that of the direct global warming effect of CFCs.

2. Historical and current contributions to Global Warming .

Since the begining of the industrial era (counted from the latter half of 18th century or early 19th century) to the present, the total increase in heat retained in the atmosphere amounts to 2.30 watts per Sq. metre of the earth's surface. The increase in concentrations of major GHGs in 1990 relative to 1765, the increased heat flux attributable to each, and the respective percentage contributions are given in Table 2.

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[1]An identical process occurs in a closed car parked in the sun.

The pattern of global warming impacts at present (1990) levels of emissions of major GHGs is displayed in Fig. 2.

It is clear that both historically, and at present, carbon-dioxide is the major contributor to increased heat retention in the atmosphere. If the potential impacts of Climate Change are indeed considered serious enough for policy measures to be adopted to counteract them, one would need to attribute responsibility for CO_2 emissions, and focus attention on its principal sources.

Who is responsible for causing Global Warming? :

Which countries or world regions bear major responsibility or the historical and present day rates of increase of CO_2 concentrations?

Fig. 3 shows the historical carbon (as CO_2) emissions from fossil fuel use (coal, oil, natural gas), cement production, and forest and soil, in gigatons for the period 1800-1987. Fig. 4 shows the historical carbon emissions over the same period attributed to fossil fuel use, which is directly related to industrial activity, broken up by major world regions. It is clear that industrialized countries (ICs) of the northern hemisphere accounted for about 85% of the total. The developing countries (DCs) have become significant emitters, only in the past two decades, and are still far below the level of ICs.

The shares of different regions in current (1987) energy related carbon emissions and in contributions to the cummulative increase in atmospheric concentrations since 1800 are shown in Fig. 5. Although currently the relative share of DCs has increased significantly over the historical accumulations (from 14.1% to 26.4%), their share relative to that of ICs continues to be small, a little more than one fourth of the total.

The disparity is more marked if one compares the per capita historical and current emissions of carbon from fossil fuel use. This is shown in Fig. 6.

These differences (both in totals as well as per capita) in emissions levels between DCs and ICs is not surprising as fossil fuel use is for the major part, related to industrial activity. However, it is clear that by far the overwhelming responsibility to date for increases in atmospheric concentrations of CO_2 (as well as of other GHGs, in particular CFCs) lies with ICs. Accordingly, the major effort for slowing the future build-up of GHGs in the atmosphere must be made by them.

What are the Effects of Climate Change? :

Before we try and answer this question, we need to know how Climate Change is predicted, and with what degree of reliability.

The most sophisticated tool for making such predictions are called general circulation models (GCMs). There are highly complex computer models of the atmosphere, incorporating smaller-scale processes. The `coupled' general circulation models (CGCMs) have the atmospheric model linked to a similar model of oceanic processes. Climatic processes are, however, extremely complex, and our understanding of climate science is yet far from complete. Moreover, for making predictions of future Climate Change it is necessary to include all the major factors, human and natural, known to affect climate. Further, it is necessary to predict the future atmospheric concentration of GHGs, which depend on various human activities. So far, GCMs (and CGCMs) have included only radiative forcing due to the GHGs component of Climate Change.

The record of earth's surface temperature warming over the past 100-130 years show a gradual warming of 0.45 $\pm$ 0.15°C. In addition some changes in precipitation at local levels have been noted over this period. A small, irregular decrease of snow cover in the Northern Hemisphere of about 8% has been observed since 1973. The accumulated evidence of such observations has led the Inter governmental Panel on Cimate Change (IPCC), a scientific body under the UN to conclude (1990 and 1992) that "the size of this warming is broadly consistent with predictions of climate models, but it is also of the same magnitude as natural climate variability. Thus the observed increase could be largely due to

this natural variaility; alternatively this variability and other human factors could have offset a still larger human induced greenhouse warming".

In other words, Global Warming due to human activities may or may not have, commenced, the actual evidence does not yet rule out either possibility.

Having said this, it must be emphasised that there are many uncertainties in the predictions of Climate Change. Some of these relate to, our inadequate understanding of, first, sources and sinks (i.e., the natural process by which GHGs are removed from the atmosphere, for example, photosynthesis). Second, the processes of uptake, retention, and precipitation of water in the atmosphere, including the role of clouds. Third, the thermal inertia and circulation changes in the oceans. Fourth, the response of polar ice-sheets, and finally, the hydrological and ecological processes on the land surface.

What are the predicted climate changes and their impacts? :

Two types of experiments (or simulations) have been conducted using GCMs (or CGCMs). In the first, the atmospheric concentration of CO_2 is doubled in one step, and the before and after equilibria are compared. In the second, of which relatively fewer simulations have been conducted, the concentrations of GHGs are increased gradually at current or predicted rates.

The predictions of the different-GCMs in existence vary within limits, in particular for surface temperature and precipitation (rain and snow). The results of some of the well known models for a doubling of atmospheric CO_2 is given in Table 3.

One simulation involving a gradual (1% per year over 70 years) doubling of CO_2 showed a global average temperature rise of 2.3°K, i.e., at the lower end of the range of predictions obtained by one step doubling of CO_2 concentrations. The reduced warming is more marked in the Southern Hemisphere. The differences in this result with that of the one step doubling CO_2 experiments emphasise the

importance of ocean processes (which have time to adjust in a gradual experiment) in controlling climate.

Given that there is still considerable divergence in GCMs' predictions, what, if any, is the consensus among scientists of probable climate changes, and the likely impacts of such changes on ecosystems? Such consensus as exists is contained in the reports of the IPCC and are briefly, as follows:

Climate Changes: There will be a gradual increase in global mean temperature during the next century of 0.3 ± 0.1°C per decade, which is greater than that observed over the last 10,000 years. The rise will not be steady because of many factors, but may mean a 1°C rise by 2025 and a 3°C rise by 2100. These temperature increases may be less if there are progressively increasing controls on CO_2 emissions.

The land surfaces will generally warm more rapidly than the oceans, and the high northern latitudes warm more than the global winter average. The regional climate changes will differ from the global average, although there is greater uncertainty about these regional changes. The temperature rise in Southern Europe and Central North America may be higher than the global average, and these regions may also have reduced summer rainfall and soil moisture. The predictions for the tropics and the Southern Hemisphere have a greater range of uncertainty.

Without significant controls on CO_2 emissions the global sea-level may rise by about 6 cm per decade over the next century (within a range of 3-10 cm per decade). Accordingly, the global sea level may rise by 20 cm in 2030 and 65 cm by 2100, with significant regional variations.

Impacts of Climate Change: Climate changes will have important effects on agriculture, forestry and livestock. While global agricultural potential may increase or decrease, there could be significant regional declines in productivity, including in Brazil, Peru, Central North America, Sahel Africa, and Southeast-Asia, Central Asia. However, there could be increases in cereal

production in Northern Europe. While policy measures and research could lessen the regional impacts, so that global food production may be maintained at the same level as without climate change, the costs are uncertain. Forests may be adversely affected because the climate changes will occur in time spans comparable to their rotation periods so that there is little scope for adaptation. In addition the host-parasite relationships may change. These stresses may be greatest in semi-arid areas.

The projected temperature & precipitation changes suggest that climate zones could shift several hundred kilometers towards the Poles in the next 50 years, a rate which is too rapid for flora and fauna patterns to adjust. Accordingly, there may be major changes in the structure of natural ecosystems.

Significant changes in water resources may accompany relatively small climate changes, induced by altered precipitation levels. However, little is known with certainty of these changes at regional levels. Many areas may have increased precipitation, soil moisture and water storage. On the other hand water availability could further reduce in some areas, and if these are already stressed, such as Sahel Africa, the result could be catastrophic. Implications for agriculture, water storage, irrigation, and hydropower may be appreciable.

GW will almost certainly accelerate sea-level rise and alter ocean circulation patterns and marine eco-systems. A 30-50 cm sea level rise, which might occur by 2050 will threaten low islands and coastal zones, while a 1 metre rise will make some island countries uninhabitable, flood agricultural land, contaminate freshwater, and displace millions of people. If drought and storms become more severe, these impacts will be heightened.

What are the policy options? :

The first thing to note in formulating policies for either reducing emissions of GHGs, or mitigating the adverse effects of Climate Change as and when they occur, or both, is that only a global response will make sense. This is becaue GHGs emissions are rapidly dispersed in the atmosphere, with the result that emissions

from any point on the globe impact all other points. In other words, emissions of equivalent GWP from different points cannot be distinguished in terms of their effects. Further, significant unilateral reductions in emissions by even the largest emitting countries, will by themselves not have major impact on the build up of GHGs in the atmosphere.

The second important aspect to be kept in mind whil framing policy, is that reducing GHGs emissions appreciably may h ve major economic costs. This is because, one, cheaper carbon intensive fuels (principally coal) would have to be substituted by costlier alternatives, such as nuclear power, or natural gas, or renewables such as solar or wind power. Two, the growth of industries such as steel making which emit large quantities of CO_2 may have to be curtailed. Three, since different countries have different levels of responsibility for causing GW, their future rights to emit GHGs should also be differentiated. This may result in changing patterns of international trade, with countries having higher relative emissions rights to GHGs gaining a competitive advantage over others with respect to GHGs intensive indutries.

The third major policy dilemma is that while there are still great uncertainties in the timing and patterns of Climate Change and its impacts, any changes in patterns of GHGs emissions may involve major economic costs up-front. On the other hand, there are serious risks of catastrophic impacts, for example major sea-level rise and increase in desertification, if nothing is done to curb GHGs emissions. Accordingly, the policy maker is faced with hard choices between a "wait and see" approach, which may involve serious risks, versus "do something now even in the absence of scientific certainty", which can involve major economic costs.

Realizing these problems and the need for cooperation, the UN adopted a two pronged approach to the issue of GW. In the first, the Inter-Governmental Panel on Climate Change (IPCC) was set up in 1988 under the Chairmanship of the eminent Swedish meteorologist, Bert Bolin, to reach international scientific consensus on different aspect of Climate Change. Two major sets of report of the IPCC (in 1990 and 1992) have been published, indicating the

areas in which there is scientific agreement and those in which there is uncertainty. In the second, an International Negotiating Committee (INC) for Climate Change was set up in 1990 to formulate a Framework Convention (or Agreement) between countries, to form the basis for schemes of international regulation of GW. The INC has had a number of sessions, and the indications are that some ageement containing a set of broad principles will be reached and signed at the Earth Summit at Rio in June this year.

Conclusion: Climate Change is clearly the most important global environmental problem yet faced by mankind. The potential adverse impact of GW are serious, and may affect key life-support systems of the planet. On the other hand, approches to the problem may involve significant economic costs, which could fall unequally across countries. The heart of the problem of reaching a future binding international agreement to limit GHGs emissions is the question of equity, or fairness. One doctrine, which has found significant support, although there are rival formulations as well, is that enunciated by Yasumasa Fujii. According to this doctrine, all human beings should have equal rights to emit GHGs, irrespective of when or where they live.

Element of the Fujii doctrine have beeen echoed in the approaches of several DCs at the INC. This principle would allow significantly greater allocation of GHGs emissions rights to DCs such as China and India, both on account of their large populations, as well as their small historical per-capita emissions relative to ICs. One needs to understand at the same time, that a sudden application of this principle globally may result in serious economic dislocation in a number of countries. Thus, while the Fujii principle remains a goal to work for in the long-term, in the short-term, various compromises are likely.

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Table 1: The major greenhouse gases

Gas	Sources	Direct Global Warming Potentials for a 100 year time horizon relative to CO_2
Carbon Dioxide, CO_2	1. Fossil fuel combustion (coal, oil, natural gas) 2. Deforestation and land use changes	1
Methane, CH_4	1. Enteric fermentation in cattle and insects 2. Biomass burning and garbage land fills 3. Coal mines and natural gas leaks 4. Rice paddies 5. Swamps and tundra	11
Chlorofluoro carbons CFCs (CFC-11, CFC-12, HCFC-22)	1. Aerosols (spray propallans) 2. Refrigeration and airconditioning 3. Plastic foams 4. Industrial solvents 5. Sterilants for medical supplies	CFC-11 : 4300 CFC 12 : 7100 HCFC-22: 1600
Nitrous Oxide N_2O	1. Fertilizer use 2. Fossil fuel combustion 3. Biomass buring 4. Changing land use	270

Sources: (1) Intergovernmental Panel on Climate Change (IPCC: 1992 IPCC Supplement.
(2) Stewart Boyle and John Ardill; "The Greenhous Effect", 1989.

Table 2: Global Warming by GHGs in 1990 relative to 1765

	CO_2	CH_4	N_2O	CFC_{11}	CFC_{12}	$HCFC_{22}$
Concentration (1765):	279	790	285	0	0	0
Concentrations (1990): units:	354 ppm	1720 ppb	350 ppb	280 ppt	480 ppt	320 ppt
Increased heat flux: (W/m^2)	1.5	0.42	0.10	0.06	0.14	0.08
% contributions :	66	18	4		12	

Note: ppm: parts per million by volume
ppb: parts per billion by volume
ppt: parts per trillion by volume

Source: John Mason: Robens Coal Science Lecture, 1990.

Table 3: Global mean changes caused by doubling CO_2 predicted by different GCMs

Model	Cloud Representation	Radiative properties of clouds	Temperature rise °K	Precipitation increase %
UKMO (1)	Empirical-linked to relative humidiy. An water clouds	Fixed	5.2	15
UKMO (2)	Computed liquid water and ice content	Fixed	3.2	8
UKMO (3)	- do -	Variable-function of water and ice content	1.9	3
GFDL	Empirical-linked to relative humidity	Fixed	4.0	8
GISS	- do -	Fixed	4.8	13
CCC	- do -	Variable	3.5	4

Abbreviations. UKMO: UK Met Office, GFDL: Geophysical Fluid Dynamics Lab, Princeton, GISS. Goddard Institute of Space Studies, CC: Canadian Climate Center, Toronto.

Source. John Mason, Robens Coal Science Lecture, 1990.

Fig. 1: A simplified representation of Global Warming.

Source: IPCC Report (1990).

Fig. 2: Relative contribution to Global Warming at 1990 emissions levels.

Source: Toufiq Siddiqi, East-West Center, based on IPCC Report (1990).

Fig. 3: Historical carbon emissions from fossil fuel use, and forest and soil, 1800-1987.

Source: Arnulf Grubler and Yasumasa Fujii (1991).

Fig. 4: Carbon emissions from burning fossil fuels by world region 1800-1987.

Source: Arnulf Grubler and Yasumasa Fujii (1991).

Fig. 5: Share of different regions in current CO_2 emissions (top) and in contributions to increases in atmospheric concentrations since 1800 (bottom).

Source: Arnulf Grubler and Yasumasa Fujii (1991).

Fig. 6: Current (1987) and cummulative (1800-1987) Carbon emissions percapita by world region.

Source: Arnulf Grubler and Yasumasa Fujii (1991).

TATA ENERGY RESEARCH INSTITUTE

TRAINING PROGRAMME
ON

ENERGY PLANNING FOR SOUTH ASIAN COUNTRIES

READING MATERIAL FOR ELECTRICITY SYSTEM PLANNING - MODELS FROM DEVELOPING COUNTRIES

BY

KRISHNA SWARUP

JAIPUR
JANUARY 1994

ELECTRICITY SYSTEM PLANNING - MODELS FROM DEVELOPING COUNTRIES

By

KRISHNA SWARUP

INTRODUCTION

Planning for power development facilities in the context of Indian systems poses several problems. One one hand, there appears to be a perpetual resource crunch for providing new facilities, while on the other the consumer looks for a safe, reliable and economic power supply to meet his demands; be it for domestic consumption, for working the agricultural pump-sets or for running the wheels of industry.

2. Over the last four decades of the Planning era, we have made noteworthy progress in power development as would be seen from the following table :-

Growth in Power Sector (All-India)

DESCRIPTION	UNIT	POSITION IN 1950-51	PRESENT POSITION (1992-93)
Installed capacity	MW	1760	72319
Energy Generation	MU	4000	30099
Transmission System			
a) 110/132 kV lines	ckt.km	2708	98000
b) 220 kV lines	ckt.km	Nil	68066
c) 400 kV lines	ckt.km	Nil	28864
Village Electrification	No	3060	491000
Pump set energisation	No	21000	9777000
No. of consumers	Million	1.5	68
Per capita consumption	kWh	15	280

However, when it comes to reliability of power supply, there seems to be a considerable gap which needs to be bridged. During the past five years, there have been peak power shortages of the order of 15-20% and energy shortage of 7-10% on an All India basis. The situation varies from Region to Region and State to State and in some cases the peak and energy shortages are much higher. The consumer is not sure of the power supply, the interruptions are frequent and load-shedding quite a common feature. Hence the need for adequate planning of Power System facilities and their time-bound implementation.

3. Electricity systems encompass generation, EHV transmission and sub-transmission and distribution systems. The various elements of the system have to be planned properly on the basis of available models so that reasonably reliable systems are available. The concept of reliability has to be suitably built up in the systems keeping in view the availability of resources and the capacity to take up huge programmes for construction etc. while planning their systems, developing countries would not be in a position to adopt reliability standards that are available in advanced countries, as it would require huge resources and manufacturing capabilities for equipment. It would be necessary to adopt suitable models and reliability indices for planning our system expansions commensurate with conditions suiting to the developing countries.

MODELS FOR GENERATION PLANNING

4. The generation planning in our country systematically started with the use of WASP (Wien Automatic System Planning) software by the Central Electricity Authority towards the late seventies. Prior to this, the planning was done more or less on a deterministic approach. The probablistic approach in the form of Loss of Load Probability (LOLP) was first employed by CEA while bringing out the Long-term Power Development Plan in 1981. The LOLP concept has been followed in the USA, the Canada and European countries and adoption of LOLP of one day in one year has been quite prevalent. That means the planning for generation additions is being done such that there would be probability of not meeting the expected demand for only one day in one year. Later LOLP of one day in five years or one day in 10 years were also adopted by some countries like USA. At present LOLP is being considered in percentage and represents the number of hours in a year for which there is likelihood of the load not being met; 1% LOLP would, thus, mean that there is probability of load not being met for 87.6 hours in a year.

5. Another concept in generation planning has been that of Energy Not Served (ENS). While the LOLP concept relates to probability of Load (peak) not being met, the ENS concept relates to the projected energy not being met in a year and is again represented as a percentage.

6. The generation planning has, therefore, to take care of both the peak load and energy requirement. This points to the need for reducing our peak demands by flattening the load-curve through various means available to us. It would not be possible to plan generation capacity additions to meet an unchecked peak demand, as it would result in huge capacity requirements and would result in backing down of stations at the time of low-load periods. It should, therefore, be the endeavor of the State Electricity Boards to achieve a higher load factor in their systems through appropriate demand management measures.

7. The Central Electricity Authority has been preparing Long-term Power Development Plans - a perspective for the next 15 years. The first National Power Plan was brought out in 1983 using the WASP software and covered the period 1980-95. For this National Power Plan, the assumptions made were;

LOLP - 1%

ENS - 1%

When the second National Power Plan was prepared in 1987 for the period 1985-2000 using EGEAS (Electric Generation Expansion Analysis System) software, it was felt that the above assumptions resulted in rather high capacity additions and a decision was, therefore, taken to adopt an LOLP of 5% and ENS of 1% in each Regional system. This question was again critically examined in 1991 while preparing the National Perspective Plan upto the year 2006-07. In this connection, the power supply position in the terminal year

of the Seventh Plan (1989-90) was studied with the EGEAS software and the studies indicated the following results :

Regionwise assessmnt of reliability levels (1989-90)

	PEAK DEMAND (MW)	ENERGY REQUIRE-MENT(MU)	AVERAGE LOLP %	ANNUAL ENS %
Northern	12742	72098	2.58	0.262
Western	11828	73267	8.99	0.262
Southern	11022	62360	3.72	3.883
Eastern	5659	30605	11.73	1.767
North-eastern	638	2716	1.18	0.162
All-India	41889	240946	5.64	1.3406

As the present power supply position more or less represents reliability levels of 5% LOLP and 1% ENS, for preparing the Long-term Plan for the next 15 years upto 2006-07, it was decided to adopt more reliable power supply than presently available. Accordingly, reliability levels of 2% for LOLP and 0.15% for ENS during the terminal year of the 10th plan were adopted.

8. The inputs that are necessary for generating planning models broadly cover the following :

- Demand projections - peak and energy;
- Shape of load Duration Curve;
- Capital cost in Rs/kW for each candidate project;
- Cost of delivered fuel and specific heat value of the fuel;
- Transportation cost of fuel;
- Auxiliary consumption in each generating station/unit;
- Forced outage rate;

- Partial outage rate;
- Annual maintenance programme;
- Heat Rate of Thermal Power stations;
- Specific fuel consumption;
- Time required for completion of each generating unit;
- Discount rate for present worth calculations.

The above inputs in the proper format are utilised in the optimisation studies for preparing Generation Expansion Plans. The aim is to prepare the most optimal plan. The studies have shown the need for capacity addition of the order of 142000 MW by the end of the 10th Plan at LOLP of 2%.

TRANSMISSION SYSTEM PLANNING

9. While the probablistic approach in generation planning has been adopted, the same is somewhat difficult in Transmission Planning, as adequate data has not been built up on the outage rate of transmission lines, transformers, switchgear, etc., which could be utilised for projecting the probability of failure of transmission lines and/or associated equipment. The deterministic approach which is based on experience has been relied upon. There is need to build up adequate data on failure of EHV transmission lines and equipment before we can switch over to probablistic approach. Power System Planning Models developed within our country and those obtained from abroad under Transfer of Technology (TOT) Programmes are being extensively employed for System Planning.

10. In a Transmission Planning Model the following important factors are required to be considered :

i) Line loadings;

ii) Fault levels;

iii) Stability;

iv) Overvoltage during switching operations.

The transmission planning has normally been done on the contingency criteria of N-1, i.e., the system should be capable of meeting the requirements in the event of outage of one EHV line or one major transformer in the system. Normally a zone or a corridor of lines should be considered while applying this criteria. The difficulty, however, arises, as in such a criteria, N-1 contingency occurs, whenever a line in a corridor is under maintenance and this does not leave adequate margin for possible outage of the other line in the corridor. Contingency N-2 may require a much larger nework and obviously a trade off between cost and reliability has to be made.

11. The fault levels are generally based on 40 KA for EHV equipment. Fault levels of 63 KA are seldom adopted, as it requires considerable design changes in the terminal equipment. For stability, the criteria of single line to ground fault close to a generating station is adopted. Here again a three phase to ground fault would result in additional system requirements. Switching over-voltage studies on the basis of EMTP are carried out to work out the requirement of reactors. Fixed line reactors of adequate

capacity (50, 63, 80 MVAR) are provided to limit the over voltages to 1.5 Pu while switching the line. For long lines, if the reactors cannot meet the requirement, a switching station enroute may have to be provided to limit the switching over-voltages.

12. In order to move towards probablistic approach in Transmission Planning, systematic data regarding faults per 100 ckt. km. of transmission line per year, per 100 transformers, per 100 switchgears etc. would be required to be collected so that the probability of occurence of faults could be reasonably predicted and systems planned with probabilistic approach.

DISTRIBUTION SYSTEM PLANNING

13. In distribution system planning, an ad-hoc approach has been by and large noticed on the part of the SEBs/ Utilities. In our enthusiasm to electrify a large number of villages, the sub-transmission and distribution systems seem to have been extended somewhat haphazardly. The urban systems too have been extended without recourse to adequate long term planning in this respect.

14. In the case of distribution planning also, no systematic fault occurrence data regarding the failure rate of overhead/underground feeders, transformers, circuits breakers or switches etc. is available, which could be used for planning purposes. Reliance has generally been kept on experience and judgement. The unauthorized loads have added to the problems of the Distribution System Planners.

15. In the case of Distribution Systems, the availability of the feeders, i.e., the number of hours it is "available" for meeting the demand of the consumer and number of hours it is "out" due to short or prolonged faults plays on important part. This, of course , is again a deterministic approach. We would be required to set a limit say 95% or higher availability of feeders, and then plan our systems. In view of the extensive nature of distribution network, information about availability/unavailability of feeders, transformers or other equipment is not generally compiled systematically and hence an ad-hoc approach in Distribution planning by most SEBs is prevalent.

16. The CEA has issued guideline from time to time for Distribution System Planning in connection with Reduction of T&D losses. These highlight the need for systematic studies at least keeping a time frame of 8-10 years in view, utilising the computer programmes now available for Distribution Planning.

17. The basic criteria for Distribution Planning would include:

i) Availability of duplicate feed at sub-transmission level;

ii) Availability of alternative feeding arrangement at Distribution level;

iii) Regulation to be within $\pm$ 6%;

iv) Provision of two transformers at sub-station with loading of 60-65% on each;

v) Optimisation of HT/LT ratio - LT lengths to be minimized;

vi) Equipment of standard rating to be employed.

18. The need for keeping an up-to-date record or fault occurrences on feeders, transformers, circuit breakers, etc. and the time period for which these were available/not available cannot be over-emphasized. This would enable us to have data regarding failures per 100 circuit Km. of distribution lines, per 100 transformers, per 100 circuit breakers per annum, so that appropriate failure rate probability could be worked out for utilising in our sub-transmission/ distribution planning in the years to come.

TECHNOLOGY UPGRADATION

19. The models for planning of generation facilities and T&D networks are being used for preparing long-term and medium-term plans for capacity additions and developing major transmission networks. The models are being upgraded with a view to having 'state-of-art' planning technology. It is also necessary that suitable training facilities are provided to the Engineers for developing skills for use of such models to deal with challenges of development. While the developing countries can make use of the Planning models and software etc. being employed by developed countries, there is need to develop their own model and software and carry out modifications to take into account the situations available in each developing country.

CONCLUSIONS

20. Power System Planning models are essential tools for generation, transmission and distribution planning to suit our requirements and prevailing conditions. The concept of reliability has to be suitably incorporated in the planning models so that investments can be kept within reasonable limits. A trade-off between investment and reliability levels, therefore, becomes necessary. There is also need to systematically collect and analyse data regarding fault levels on transmission and distribution lines, transformers and associated switchgear, so as to evolve reliability indices on the basis of probablistic approach for adoption in our planning for T&D networks. It is also necessary that human skills are developed with proper training to meet the challenges of planning adequate generation and transmission systems, keeping in view the complex energy - environment scenario in developing countries.

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Issues in the Hydrocarbon Sector in South Asia

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Energy supply in South Asia is characterised by varying dominance of traditional fuels. While the share of traditional fuels for the region as a whole has been coming down over the years, it is still over 90% in Nepal and is around 40% in India and Pakistan. The percentage share of traditional fuels in the other countries in this region would lie somewhere between this range.

2 These countries are also relatively poorly endowed with commercial energy resources While India has large coal deposits and Bangladesh, India, Pakistan and Myanmar have hydrocarbon reserves, these are quite limited compared to total world resources and are unevenly distributed. The resources of this region are :

Coal and Lignite	5 7% of world reserves
Oil	0.7% ""
Natural Gas	2 1% ""

3 As regards hydrocarbon resources, while India has the largest of the oil reserves within this Region, Bangladesh accounts for the largest gas reserves Table 1 brings out the position

Table 1.

Hydrocarbon Resources
1989

	Oil (Million Barrels)	Natural Gas (Billion M^3)
Bangladesh	40 (0.6)	1050 (38 1)
Pakistan	225 (3 1)	734.18 (26 6)
Nepal	--	0 042 (Negligible)
Myanmar	1482 63 (20.4)	288.54 (10.5)
India	5549.00 (76.0)	686.45 (24.9)
Total	7210 63	2487 032

Figures in Brackets show percentage share in the Region.

4. The shares of Oil and Gas in primary commercial energy supply in these countries have been dictated as much by local resource endowments as the patterns of development experienced. The shares of some of the countries in this region are :

Table 2

Share of Oil and Gas in Primary Energy Supply (in %)
1990

	Oil	Gas	Others
Bangladesh	34	60	6
India	33	6	61
Nepal	64	--	36
Pakistan	45	41	14
Sri Lanka	80	--	20

As can be seen from the above, hydrocarbon account for 80% or more of the commercial energy supply in Bangladesh, Pakistan and Sri Lanka, while the shares of other forms of commercial energy are somewhat higher in India and Nepal. This is because of relatively greater use of coal (over 55% of primary energy supply) in India and hydro-power (over 25% of primary energy supply) in Nepal.

5. The Oil and Gas reserves in India have registered significant increases in the last two decades However, the growth rates for new discoveries have somewhat slowed down leading to increasing import dependence Natural Gas has emerged as an increasingly important source of energy particularly in Bangladesh, India and Pakistan Also, the reserve-production ratio for Natural Gas in these three countries is relatively more comfortable than for oil

6. While primary commercial energy availability has increased by about 7% during the 1980s in this region, the rates of growth of consumption of petroleum products (including refinery fuels and bunker sales) vary from country to country as can be seen from Table 3.

Table 3

Rates of Growth in 1980s

	Consumption of Petroleum Products	Primary Commercial Energy Availability
Bangladesh	1%	7 2%
India	6.4%	6 5%
Nepal	5 9%	7 9%
Pakistan	8.0%	7 6%
Sri Lanka	0.5%	2.0%

Bangladesh has registered a significant growth in consumption of natural gas during this period. Similarly, India and Pakistan have also registered substantial increase in gas consumption

The end-use patterns of oil provide some interesting pictures.

Table 4

Sectoral Use of Oil (in %)
1990

	Industry	Transport	Power	Others (including non-energy use)
Bangladesh	5	30	21	44
India	20	43	5	32
Nepal	2	39	12	47
Pakistan	12	51	17	30
Sri Lanka	8	67	5	20

It is clear that the most dominant use of oil will continue to be in the Transport Sector for which there is no substitute for oil. Compressed Natural Gas is yet to become a viable commercial proposition for the Transport Sector

8. As regards Natural Gas, the consumption pattern is broadly as follows:-

Table 5

Sectoral Consumption of Natural Gas

(in %)

	Power	Chemicals & Petrochemicals	Residential	Others
Bangladesh	42	39	6	13
India	31	47	0 5	21 5
Pakistan	55	27	14	4

While Bangladesh and Pakistan have encouraged gas-based power, India wanted to allocate the additional gas availability primarily for fertilizer production However, more and more gas is now being allocated for power generation in India with the result that the Power Sector will account for the largest gas consumption in India within the next few years

9 Another important aspect of energy and oil consumption in these countries is the low per capita energy consumption and increasing energy and oil intensity The following Table brings out the per capita energy consumption.

Table 6

Per Capita Commercial Energy Consumption, 1990 (Kgoe)

Bangladesh	57
India	231
Nepal	25
Pakistan	233
Sri Lanka	179
World Average	1567

10 It is clear that, with increasing shift from traditional to commercial fuels, changes in income structures and the anticipated economic growth, the import dependence for hydrocarbons for this region will increase in the coming year.

Some of the major issues that emerge from the resource and the consumption pattern of hydrocarbons in this region are briefly discussed below

11 The exploration efforts in Bangladesh, India, Myanmar and Pakistan can be significantly accelerated. The exploration density in India (1 2 wells per 1000 sq. kms.) is the highest in this region, but falls significantly short of the world average of 9.5 well per 1000 sq kms. There is also considerable scope for enhanced oil recovery and introduction of new technologies in this regard.

12 Efficient use of energy is another important task in this region Various estimates have been made about energy consumption potential in these countries Such potential for the Industrial Sector has been estimated to be 22% in Pakistan. Similarly, studies in India have established energy conservation potential of around 25% in the Industrial Sector. The national energy conversion losses as part of percentage of total energy supplies have been estimated as follows :-

Table 7

Energy Conversion Losses as % of Total Energy Supply

	1980	1989
Bangladesh	25 0	31 9
Nepal	17.3	21 9
Myanmar	35.5	39 9
Pakistan	33 4	28 7
Sri Lanka	26.9	23 3
India	33 2	37.6

13 Potentials of energy conservation can be achieved by appropriate packages of incentives and disincentives, inter-fuel substitution, appropriate pricing, institutional changes, etc According to an ESCAP study for Bangladesh, Nepal, Pakistan, Sri Lanka and India, the primary commercial energy requirement of 7655 Pj in 1986 for these countries will go up to 27456 Pj by

2010 in the `Business As Usual' scenario, while the requirement would come down to around 21000 Pj if full conservation and fuel switching potentialities are achieved.

14. The institutional structure also becomes important in this respect. The exclusive reliance on public sector for energy supply in India has led to inefficiencies in certain areas. The process of opening the energy sector to private entrepreneurs has assumed particular importance for improvement in efficiency and for reflection of market forces Appropriate pricing policies would also be necessary to ensure proper resources allocation and wasteful use of oil products in particular and energy in general The scope of regional cooperation can also be pursued to the mutual benefit of the countries in this region Regional cooperation in use of Natural Gas, Hydel power and Coal could optimise the use of available resources in this region.

15 Cost and security of adequate supplies of oil and oil products will continue to be matters of concern for the countries of this region. Greater development and use of the regional resources, efficient use of all forms of energy including oil and gas and appropriate institutional changes would to a large extent act as mitigating factors.

Energy Demand in Agriculture

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ENERGY MANAGEMENT IN AGRICULTURE AND RURAL SECTOR

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India has made considerable progress towards increasing agricultural production and productivity. Her strive to meet future food, feed, fibre and fuel requirements for its growing population, however, is a continuing one. Commercial energy from oil, coal, natural gas and electricity has been the foundation input for modernisation of agriculture and development of industries. The high productivity model of developed nations based on intensive use of commercial energy is not suitable for developing because of the rapidly increasing price of commercial energy sources, their exhaustible nature and their ever increasing rate of depletion. It is, therefore, important to explore new sources to meet the energy needs of agriculture and agro-based industries. The needs of rural kitchen which account for over fifty percent of total energy use in agriculture and industries put together is also an important consideration. Agriculture of future will be required not only to produce more food but also to generate energy to cope with the increased demands.

1. Energy Use Pattern at Macro-level for Agriculture Production

Agricultural productivity is dependent upon improved seed of high genetic potential and efficient use of water and energy

of chemical or biological origin. An analysis (2) of energy use for agriculture in various states of India during the last three decades (1961-91) shows that while the input through animate energy (Draught Animal Energy and Human Energy) have remained more or less constant, the use of diesel and electricity, agricultural machinery and chemical fertiliser has increased by 24.[illegible], [illegible] and 24.5 times, respectively (Table 1).

The highest energy input use in production agriculture during 1961 to 1981 (Table 2) has been registered by Punjab (27[illegible]%), followed by Haryana (212%), Andhra Pradesh (12[illegible]%), and Uttar Pradesh (10[illegible]%). The states which increased energy use by more than 75% are Kerala (92%), Karnataka (86%), West Bengal (84%), Maharashtra (82%) and Rajasthan (77%). States with relatively smaller increases of input energy use are Assam 16%, Orissa (31%), Jammu & Kashmir (37%), Bihar (55%), Himachal Pradesh (64%) and Madhya Pradesh (70%).

The statewise productivity index and energy use index for the period 1961-81 is presented in Table 3. In spite of variations in factors such as farm size, cropping patterns, methods and sources of irrigation, cultural practices, sources of power used etc. there is a correlation between the level of energy use and productivity. However, the increase in productivity has been realised through commercial energy sources only i.e chemical fertiliser, diesel and electricity. A study conducted at Punjab Agricultural University has (4) revealed that during a 15 year period from 1965-66 to 1979-80 the total food grain production of Punjab increased by 175%, 12.5% annually,

During this period the total energy input increased by 267%, at the rate of 27.6% per year.

Can higher productivity be achieved also through alternate energy sources? This is an important and vital matter deserving of serious consideration.

1.1 Energy substitution - the role of biogas slurry

Energy as chemical fertiliser is the single largest energy input to production agriculture constituting 40 to 55% of the total energy input (2). Recycling of dung through biogas plants provides not only cooking energy but also plant nutrients for crop production. The requirement of chemical fertilisers can also be reduced to an extent by practices for maintaining soil fertility such as crop rotation, catch cropping, lay farming with legume rotation and recycling of crop and livestock residues. Research has led to availability of a range bio-fertilisers such as rhizobium, blue green algae and azolla on commercial scale.

Under the All India Co-ordinated Research Project on Renewable Sources of Energy, field experiments have been conducted at IARI, New Delhi, CIAE, Bhopal, TNAU, Coimbatore, SFCW, Courtallam and UAS Dharwad on the use of biogas spent slurry as partial replacement to chemical fertilizer. Different crop rotations and different treatment methods were tried both in Kharif and Rabi seasons. Results have shown that the chemical fertilizer can be replaced to the extent of 50 to 75% for achieving the same yield. Besides, residual effect of slurry gave comparatively higher yields, and resulted in improved soil conditions.

1.2 Alternative energy sources for motive shaft power

The pumping energy is the next largest energy input for crop production. There are over 4 lakhs diesel pumpsets and an equal numbers of electrical pumpsets. Such pumps consume about 15[illegible] crores kWh electricity and about 5[illegible] crores of LDO/HSD. The supply of electricity is erratic in rural areas. The pump sets can be energised with biogas engines and gasifiers working on agriculture residues as feedstock. Atleast 4 designs are commercially manufactured in the country . However, there is need to improve the technology, after sales service and repair and maintenance services for these gadgets. Alternate sources of energy are encouragingly becoming cost competitive. Mittal and Dhawan (5) have reported that irrigation accounts for up to 6[illegible]% of the total energy requirement for crop production.

1.3 Improved tools and implements for energy saving and enhancing production

It has been shown that 15 to 20% increase in food production can be obtained by timeliness of operation made possible by improved tools and equipments. The increased production is realized at lower cost and savings in energy consumption.

In one study on use of improved animal drawn implements led to a saving of 44.[illegible], [illegible], 5[illegible] and [illegible]% in energy for production of wheat, rice and, cotton and pearl millet, respectively . Average increases in yield of 5.4, 17.4, 14.[illegible] and 1[illegible]% and saving in cost of operations upto [illegible]1.[illegible], [illegible].[illegible], 4[illegible].[illegible] and [illegible].4%, respectively, were observed by the adopting improved technology for energy utilization in the agricultural sector.

2. Energy Use Pattern at Micro-Level (Case Study of A Village)

The example of the village Islamnagar in the District of Bhopal, Madhya Pradesh, which has [illegible] households with a total population of [illegible] and livestock population of [illegible] is instructive. An energy Census and Resource Assessment Survey revealed the following:

i) Among the four major activities in the village, energy for crop production accounted for 14.5%, post harvest operation about [illegible].5%, cattle raising about 1% and domestic activities (mainly cooking) 84% (Fig 1).

ii) Thirtysix percent of the population (the largest category) is of landless people. This group accounts for [illegible]% of total energy use in the village. There is no agency which cares for the energy supply to the landless people.

iii) Out of the [illegible] TJ of solar energy, that is received annually by the geographical landmass of [illegible] ha of this village, only 4.4[illegible] TJ is converted into food, feed, fuel and fibre indicating an overall photosynthetic efficiency of only [illegible] percent as compared to the world average of [illegible] percent (Fig 2).

iv) The village was surplus in cereals, vegetables, sugarcane and milk. However, there were annual deficits: for fuelwood by [illegible]% ([illegible] tonnes), cattle feed by [illegible]% ([illegible] tonnes), oilseeds by 71% ([illegible] tonnes) and pulses by [illegible]% ([illegible] tonnes), (Fig 1).

v) The village has 61 ha of wasteland and 133.6 ha of pasture land which have the potential to make the village self-sufficient and also surplus with regard to firewood and cattle feed.

3.1 Planning for Decentralised Energy Supply System

The integrated energy census survey was used as basis for planning and implementation a scheme of development for achieving self-sufficiency in fuelwood, fodder, pulses and oilseed production and its processing at the village level. The inspiration was the Gandhian Concept. The reallocation of land, based on Soil Survey and Land Use Planning as prepared by the National Soil Survey and Land Use Planning Bureau, Nagpur (5) has led to self-sufficiency planning in pulse and oil seeds production by taking into account an efficient soil and water management plan [illegible] and a package of improved tools and implements. The [illegible] intensity which was [illegible] in 1981 has gone up to [illegible] in [illegible]. The fuelwood deficit was eliminated through plantation of 34,[illegible] trees belonging to 24 species on [illegible] ha. In addition, [illegible] trees of [illegible] existing plantations were regenerated. The ecosystem was enriched in number and variety of birds and wildlife animals such as wild pigs and a pair of wolves, etc. If all the [illegible] ha of waste land could be brought under afforestation, the village would have become surplus in fuelwood production. Growing of grasses on the wasteland and pasture land can reduce the [illegible] deficit to the extent of [illegible]. The village has 133 ha of pasture land mostly under illegal encroachment which can be retrieved through social action. Installation of 5 individual biogas plants and three community biogas plants of 35, 35 and 85 cum per day led to the

production of 72,000 cum of biogas and 570 tonnes FYM from the biogas slurry which could take care of 5 % of the cooking energy needs of the village and 25% of Nitrogen requirement of the village for achieving self-sufficiency in cereals, pulses and oilseeds.

Implementation of various programmes for making the village self-sufficient can lead to better resource utilisation and increased harnessing of solar energy for conversion into food, feed fuel and fibre. It is important to note that when the ecosystem becomes self-reliant and sustainable, the actual energy requirement of the village goes down, from 16 TJ to 15.5 TJ annually. The production efficiency increases by (i) reduction in wasteful use of thermal energy through traditional stoves and achieving higher thermal efficiency through biogas burners and (ii) harnessing of solar energy for additional food, fuelwood and grass production. The solar energy conversion goes up from 4 TJ to 67 TJ leading to overall photosynthetic efficiency to an average of 0.144% against the original efficiency of 0.0583%.(Fig.3) The new production agriculture, post-harvest operations and afforestation programmes generate additional 1,[illegible],000 man-hrs year ([illegible].5 man-days) (Table 4). In other words, 4 persons could be gainfully employed for 300 days a year. Table 5 presents the impact of on productivity & Socio-economic conditions in village Islamnagar.

It is thus obvious that alternate energy sources play an important role in agriculture. The example can become a trend setter for other sectors and a way to profound changes in life style and standards.

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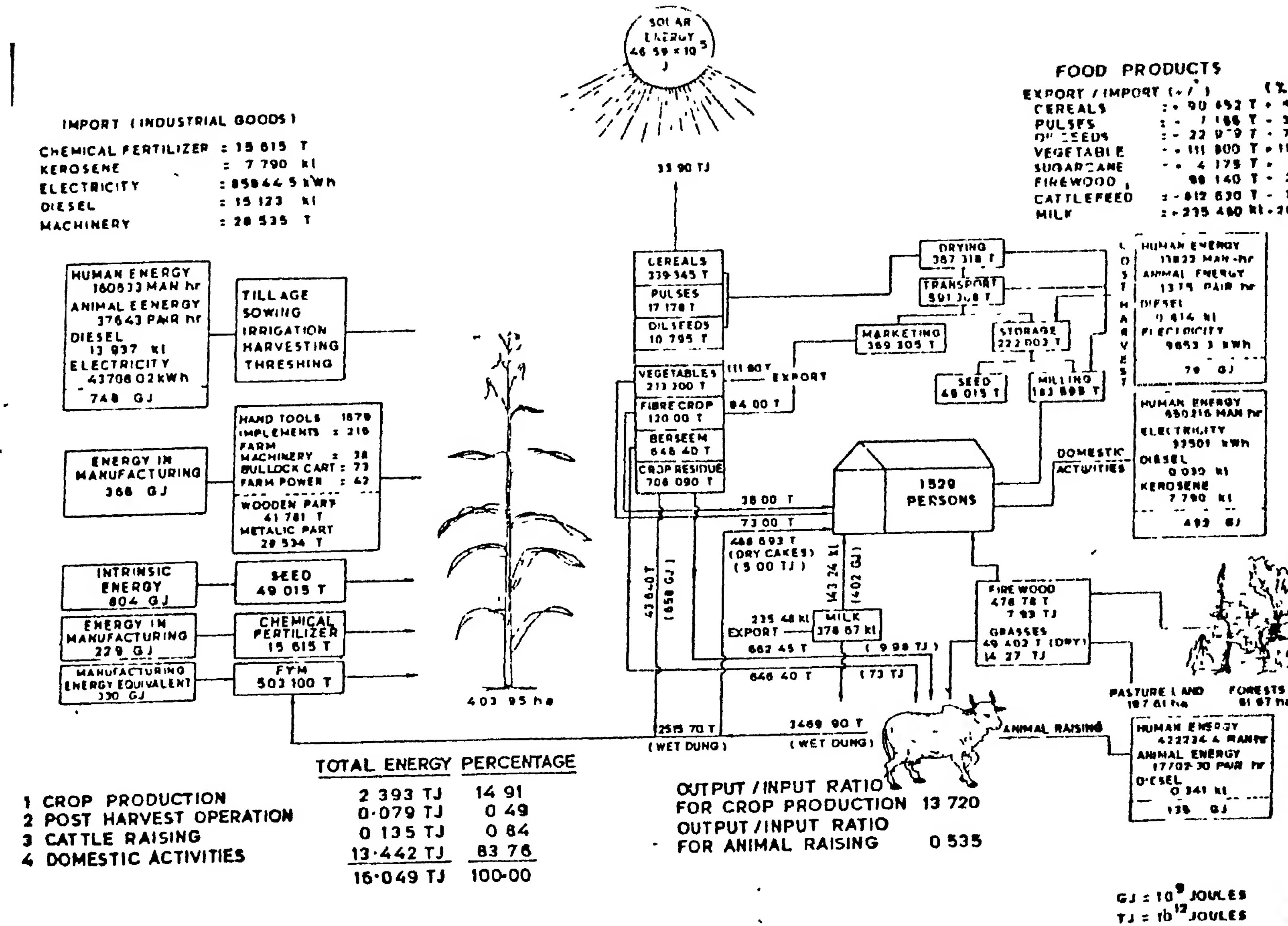


FIG 1 ANNUAL ENERGY FLOW IN VILLAGE ECOSYSTEM

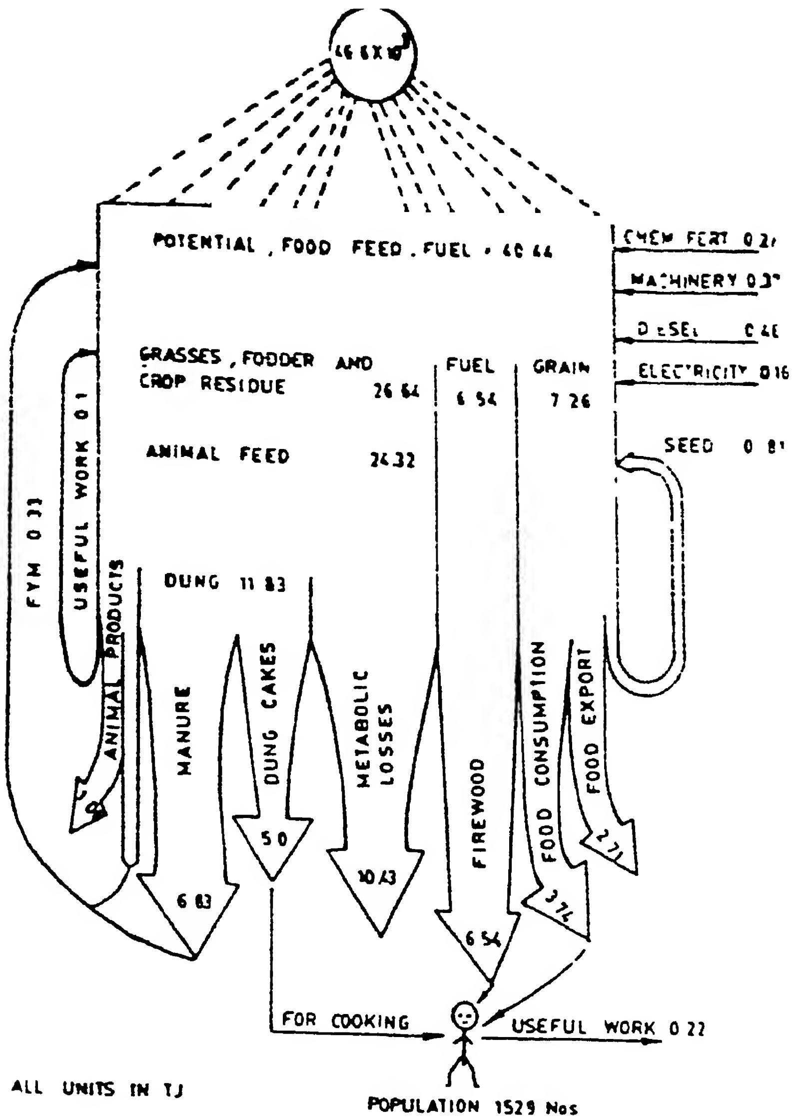
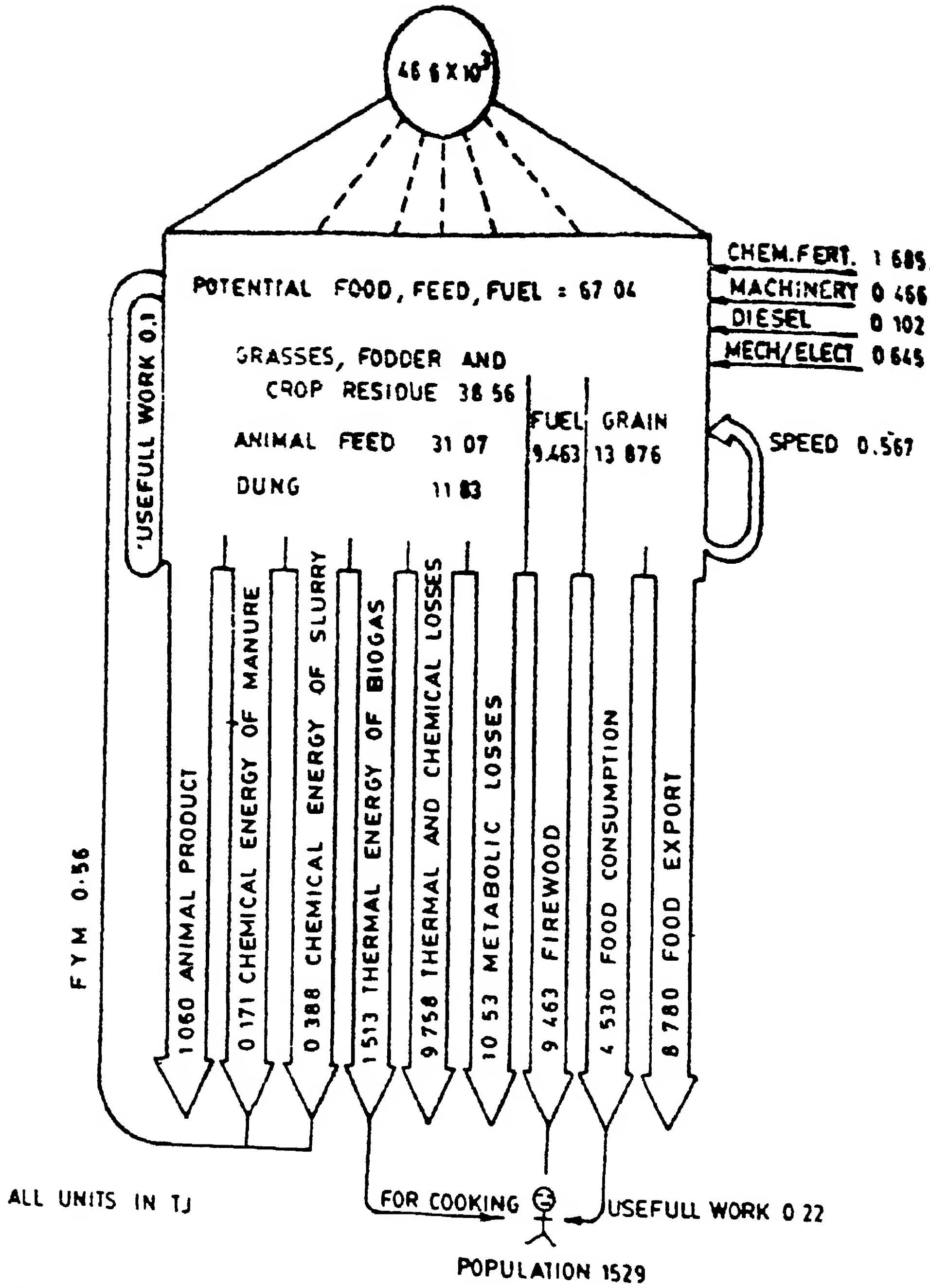


FIG 2 SANKEY DIAGRAM ILLUSTRATING SOLAR ENERGY FLOW IN THE VILLAGE ECOSYSTEM IN 1981



OVERALL EFFICIENCY OF THE VILLAGE ECOSYSTEM	0 1438 %
OVERALL EFFICIENCY OF THE VILLAGE ECOSYSTEM AT 1981 LEVEL	0 0868 %
INCREASE IN OVERALL EFFICIENCY	0 0570 %
INCREASE IN OVERALL EFFICIENCY W R T 1981 LEVEL	65 7000 %

FIG 3 SANKEY DIAGRAM ILLUSTRATING SOLAR ENERGY FLOW INTO VILLAGE ECOSYSYSTEM AT SELF-SUFFICIENCY IN FOOD FEED, AND FUEL

Table 1 : Category-wise All India Energy Input in Production Agriculture

Sl. No.	Category	Input energy source	Form & type of energy	Year		
				1960-61	1980-81	1990-91
1.	A	Animate energy human and animal	Direct non-commercial	81569 (22.10%)	116600 (14.25)*	1[illegible] (10.75)
2.	B	Seed & Farm yard manure	Indirect non-commercial	237373 (64.45)	277245 (35.30)	[illegible] (22.77)
3.	C	Diesel & electricity	Direct commercial	10549 (2.65)	99461 (12.66)	253075 (20.10)
4.	D	Farm implements & machinery	Indirect commercial	175[illegible]5 (4.75)	39349 (5.01)	577[illegible] (4.53)
5.	E	Fertilizer & chemicals	Indirect commercial	21602 5.83	252670 (32.17)	53[illegible]623 (42.16)
		Total		368887 100%	785325 (100%)	12535[illegible] (100%)

* Figures in parenthesis are %age of the total energy input.

Table 2 : State Wise Energy Input to Production Agriculture during the Years 1961 to 1981

Sl. No.	State	Level of Energy Input TJ UNITS		
		1961	1981	%
1.	Andhra Pradesh (5)	42,636	94,134	120.9
2.	Assam	9,193	10,672	16.1
3.	Bihar	29,450	45,600	54.8
4.	Gujarat (3)	20,500	62,225	203.5
5.	Haryana *(2)	9,616	30,019	212.2
6.	Himachal Pradesh	2,036	3,347	64.4
7.	J and K	2,434	3,328	36.7
8.	Karnataka	23,574	43,778	85.7
9.	Kerala	5,989	11,517	92.1
10.	Madhya Pradesh	37,378	63,354	69.5
11.	Maharashtra	38,348	70,296	83.3
12.	Orissa	17,773	23,241	30.8
13.	Punjab *(1)	17,617	65,234	270.5
14.	Rajasthan	25,601	45,526	77.8
15.	Tamil Nadu (4)	24,376	62,643	157.0
16.	Uttar Pradesh (6)	71,288	146,690	105.8
17.	West Bengal	17,302	31,853	84.1

* 1965 level as these states were formed in 1965.

Table 3 : Statewise Productivity Index and Energy Use Index For 1981.

Base 1971 as 100

Sl. No.	State	Yield Index	Energy Use Index
1.	Orissa	81.1	116
2.	Himachal Pradesh	104.8	118
3.	West Bengal	106.7	156
4.	Kerala	107.1	139
5.	Madhya Pradesh	108.9	133
6.	J & K	116.1	137
7.	Bihar	122.9	128
8.	Uttar Pradesh	127.7	144
9.	Rajasthan	134.8	13[illegible]
10.	Tamil Nadu	135.4	138
11.	Andhra Pradesh	140.1	171
12.	Haryana	141.4	198
13.	Karnataka	142.5	139
14.	Gujarat	147.8	158
15.	Punjab	158.4	183
16.	Maharashtra	159.0	136
	All India	127.8	148

Table-4 [illegible] Man Power Requirement and Employment Generation at Self-sufficient Level

Sl. No.	Operation	Manual energy at 1981 level Man-hrs	(%)	Manual energy at self sufficiency level Man-hrs	(%)	Additional manual energy/ Generation/ reduction (+) Man-hrs	(+) (%)
1.	Crop production	1,60,6[illegible]	[illegible]	1,[illegible]	[illegible]	+ [illegible]	+ 4.27
2.	Post harvest activities	13,6[illegible]	2.47	[illegible]	4.17	+ 9,499	+ 1.701
3.	Domestic Activities	6,50,216	116.09	5,04,946	90.54	1,45,510	- 26.05
4.	Cattle raising	4,2[illegible],2[illegible]4	75.58	4,[illegible],664	78.70	+ 17,430	+ 3.12
5.	Energy Plantation	--		1,15,307	20.64	+1,15,307	+ 20.64
6.	Grassland management	--	-	78,914	14.13	+ 78,914	+ 14.13
7.	Milk marketing	24,964	4.47	24,964	4.47	Nil	Nil

Overall increase in man hrs = 1,00,057

Hence, total man-days generated = $\frac{100057}{8}$ = 1,507 man-days/ yr.

Table 5 Impact on Productivity, Socio-economic Conditions & Employment Generation in the Village Islamnagar

Sl No.	Item	Technological & Economic Changes		
		1981 Scenario	1986/90 Scenario	% Change
1	2	3	4	5
I.	**Changes in Village Ecosystem**			
1.	Total villagers	1,529	1,726	12 9
2.	No of households	224	253	11.5
3.	No. of farming households	131	121	-(4 5)
4	No of landless households	93	132	17.4
5.	No of catles	1,427	1,648	13.4
II.	**Changes in Agricultural System**			
1	Net cultivated land (ha)	403 88	430.76	6 7
2.	Total cropped area (ha)	402 00	583.43	44.5
3.	Cropping intensity (%)	99 50	135 40	36 1
4	Total irrigated area (ha)	196 27	267 28	36 0
5	Use of chemical fertilizers (kg/ha)	39 00	110 72	183 9
6.	Productivity (tonnes/ha)	0.986	1.43	45 0
7.	Storage capacity of water harvesting pond (ha-m)	3.53	7.14	102.3
8.	Total deiesel consumption (Litres)	13,938	22,694	66 8
9.	Toral electricity Consumption (kwh)	43,708	75,399	72.5
III	**Change in Environment and Ecology**			
1.	No of trees possessed by the farmers	1,200	2,285	90.4
2	Original rootstock regenerated due to protection	..	10 886	—
3.	Total trees in the ecosystem (No)	1,200	25,897	2141.4
4	Tree species in the ecosystem (No)	20	44	120 0

1	2	3	4	5
V	Status of Biogas Technology			
	1 Individual biogas plants installed (Nos) ...		44	
	2 Community biogas plants installed (Nos) -		3	
	3 Biogas generated (cum yr)		40 647	
		(Potential)	64 824	
	4 Cooking energy met throgh biogos technology		32%	
		(Potential)	52%	
	5. Annual availability of slurry (tonne)		326.8	
		(Potential)	518 6	
	6 Plant nutrient (N) met through sulrry		16%	
		(Potential)	28%	
V.	Employment generated & Drudgery Removed			
	1. No of man-days used for			
	a] Crop production activities	20,079	23,127	15.2
	b] Post harvest activities	1,628	2,915	68 7
	c] Cattle raising	52,779	54,950	22.3
	d] Energy plantation	....	14,412	....
	2 Drudgery reduced (women days) in domestic activities	81,277	63,188	-22.3
VI	Chaneg in Economic Indicators			
	1. Net return/ha (Rs./ha) (base year 1988-89)	1,769	3,310	91.1
	2. Net return per farmer, Rs. (base year 1988-89)	737	2,125	188 4
	3 Benefit cost ratio	1 583	1 895	19.7

Rural Energy Scenario

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Training Programme
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Rural Energy Issues in SAARC countries

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Regional Profile

The SAARC region, comprising of Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka, is among the most backward regions in the world[1] All the countries are in the category of under-developed nations characterized by high population density, high population growth and low rate of economic development The region has a population of 1 13 billion, ranging from 853 million in India to a tiny 0 2 million in Maldives, accounting for more than one-fifth of the world population[2] The population density, except for Bhutan, is pretty high ranging from 1400 per thousand hectares (ha) in Nepal to as much as 8880 in Bangladesh Annual population growth rate is also high ranging from 2 07% in India to 3 44% in Pakistan

An important feature of the region is a predominance of rural population with agriculture as the primary occupation The proportion of rural population ranges from 68% in Pakistan to 95% in Bhutan (Table 1) The per capita GNP is very low in the region varying from US$ 170 for Nepal to US$ 430 for Sri Lanka This is in sharp contrast to developed countries such as Japan (US$ 23730) and United States (US$ 21100), and rapidly industrializing countries like Brazil (US$ 2550) The lifestyles in the rural areas are mostly at subsistence level and essentially biomass-based.

Table 1: Basic indicators for South Asian Region

Country	Population (million) (1990)	Annual growth rate (%) (1985-90)	Rural population (%)	Total area (000 ha)	Population density (per 1000 ha)	Per capita GNP (US $)
Bangladesh	115 6	2 67	83 4	13017	8880	180
Bhutan	1 5	2 15	94 7	4700	323	190
India	853 1	2 07	73 0	297319	2869	350
Nepal	19 2	2 48	90 4	13680	1399	170
Pakistan	122 6	3 44	68 0	77088	1591	370
Sri Lanka	17 2	1 33	78 6	6463	2664	430

[1] Due to paucity of information Maldives has been excluded from the analysis of this paper

[2] All the basic statistics are, unless otherwise stated, from World Resources (1992-93), Published by World Resources Institute

Landuse pattern in the region varies considerably across the countries with significant amount of land being under cultivation or forests. For instance, nearly 57% of total land in India is cropland while 55% and 48% land is under forest cover in Bhutan and Nepal, respectively. (Tables 2 and 3) As mentioned earlier, the primary occupation in the region is agriculture, mostly rainfed Except for Pakistan, where 78% of total cropland is irrigated, the level of irrigation is low in all other countries, ranging from one-fourth to one-third of the total cropland. Major crops in the region are paddy, wheat and pulses.

Table 2: Landuse pattern 1987-89 ('000 ha)

Country	Total	Crop land	% of irrigated cropland	Pasture	Forest & woodland	Other land
Bangladesh	13017	9217	26%	600	1966	1180
Bhutan	4700	130	26%	270	2600	1700
India	297319	169357	25%	11923	66782	49257
Nepal	13680	2600	34%	1997	2480	6603
Pakistan	77088	20770	78%	5000	3293	48025
Sri Lanka	6463	1898	29%	439	1747	2379

Table 3: Indicators of forest cover (1987-89)

Country	Forest & Woodland (000 ha)	Per capita forest (ha)	% of forest land to total land (1981-85)	Rate of deforestation % (1981-85)	Rate of afforestation (000 ha)
Bangladesh	1966	0 017	15 1	0.9	817
Bhutan	2800	1 87	55 3	0 1	11
India	66782	0 08	22 5	0 3	147138
Nepal	2480	0 13	48 3	4.0	844
Pakistan	3293	0 027	4 3	0 4	97
Sri Lanka	1747	0 102	27 0	3 5	5813

Figures on livestock population vary sharply across the countries (Table 4) In terms of human-animal ratio, Bangladesh has just one animal per 31 people while Pakistan and Nepal have the best ratio of one animal per 1 2 people However, as far as total number is concerned, India has the largest livestock population in the world at a ratio of one animal per two people

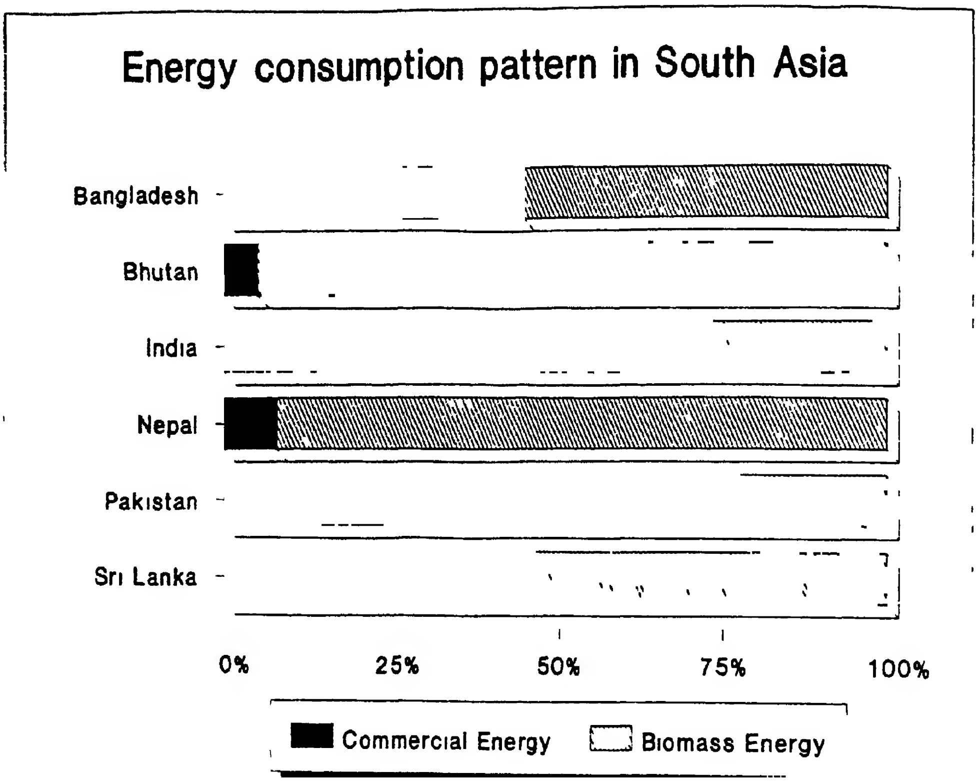
Table 4: Livestock Population

Country	Cattle	Buffaloes & Camels	Goat & Sheep	Others	Total	Human & livestock ratio
Bangladesh	23102	1757	12083	45	36987	31 1
Bhutan	408	4	86	123	621	2 4 1
India	195267	74980	160586	12819	443652	2.1
Nepal	6303	2989	6171	546	16009	1 2 1
Pakistan	17364	15325	62562	3633	98884	1 2 1
Sri Lanka	1816	971	546	97	3430	5.1

Energy consumption pattern

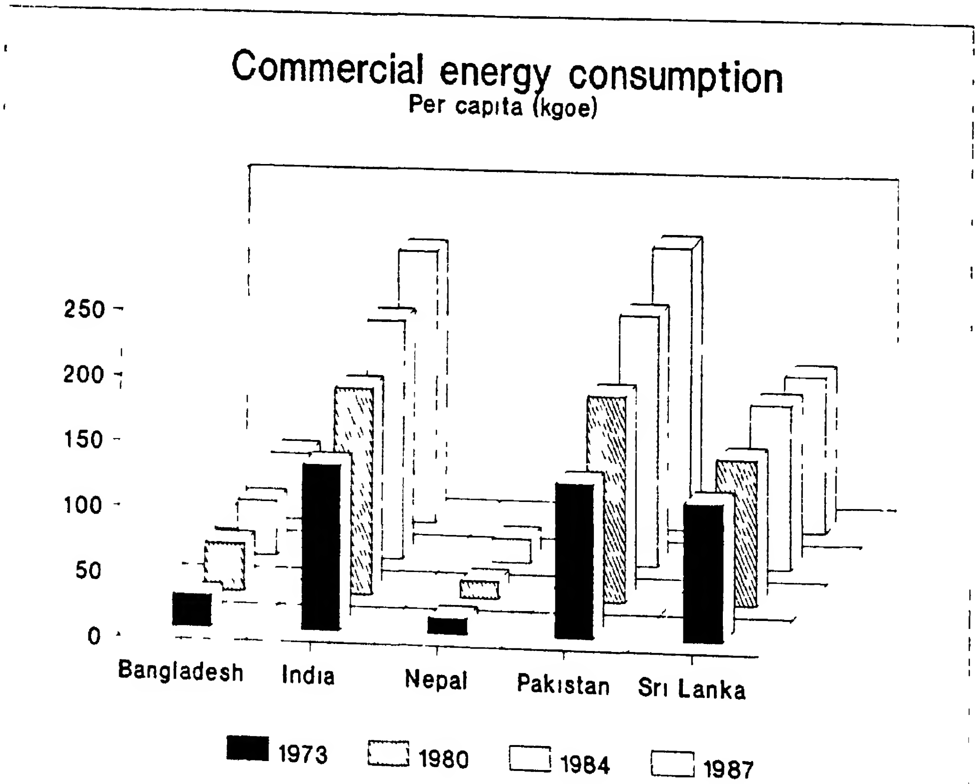
The energy scene in the region is characterized by very low per capita energy consumption ranging from 5 Gigajoules (GJ) in Bangladesh to 22 GJ in Bhutan, being only a fraction of per capita use in oil-rich countries like Qatar (593 GJ) and UAE (581 GJ), and the United States (324 GJ) In all the countries in the region, except for India and Pakistan, the energy scene is dominated by the biomass fuels In these countries, a major proportion of the total energy consumed comes from biomass sources - 52% in Sri Lanka to 95% in Bhutan For India and Pakistan the figure is less than 25% (Figure 1). However, in all the countries barring Bhutan, the consumption of commercial energy resources (oil, coal and electricity) has been going up steadily, both in total quantity and per capita terms (Figure 2). For instance, between 1973 (the year of oil crisis) and 1987, commercial energy use went up by 3 times in Bangladesh and Pakistan, 2 times in India and Nepal, and 1 5 times in Sri Lanka

Figure 1



Source World Resources 1992-93

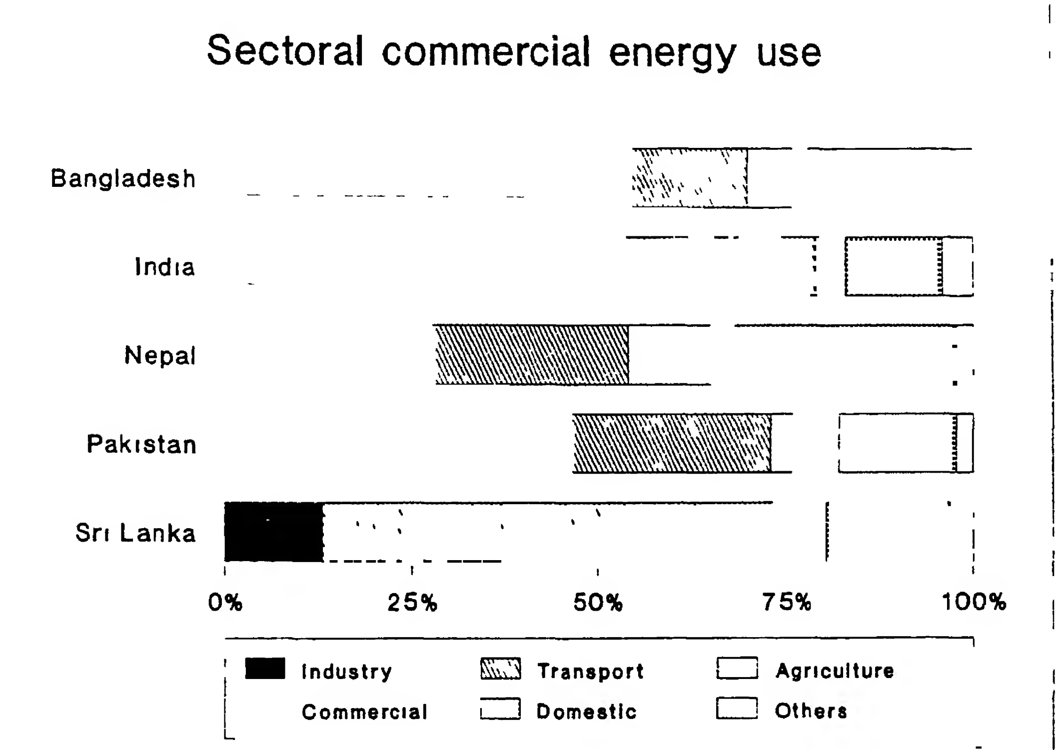
Figure 2



Source ADB 1989

Sectorally, industry and transport are the major consumers of commercial fuels in all the countries - both combined consuming from 54% of commercial energy in Nepal to 78% in India (Figure 3) However, in Sri Lanka transport is the principal sector accounting for 61% of the total energy Domestic sector is also prominent consuming 13% in India to 30% in Nepal

Figure 3



Source World Resources 1992-93

As far as non-commercial (biomass) fuels are concerned, almost the entire consumption is in the rural areas, meeting an overwhelming proportion of the energy needs. In the rural areas, households are the most prominent sector accounting for most of the biomass consumption The present energy scenario in different countries, based on available information, is described below[3]

India

The most detailed information on energy consumption pattern in India on a rural-urban basis was published in 1985 (Table 5), according to which 89% of the total energy in the rural areas was contributed by the non-commercial fuels (NCAER 1985) Several of the regional and micro level consumption studies carried out since, also validate most of the patterns indicated by the NCAER study.

Table 5: Rural energy consumption pattern in India

State	Kerosene	Total commercial	Logs	Twigs	Charcoal	Crop waste	Dung	Total non-commercial
Andhra Pradesh	8 7	10 2	22 4	48 1	0 2	10 4	8 4	89 5
Assam	9 7	10 5	45 0	24 4	0	20 1	0	89 5
Bihar	3 7	7 8	4 3	26 9	0	19 9	41 1	92 2
Gujarat	26 3	32 7	14 6	39 6	0 1	2 7	14 7	66 7
Haryana	4 2	9 4	5 6	13 8	0	27 3	43 9	90 6
Himachal Pradesh	7 4	12 1	44 0	44 1	0	0 4	0 7	88 9
Jammu & Kashmir	5 9	9 7	23 6	39 0	1 8	3 0	22 9	90 3
Karnataka	6 5	9 3	22 7	51 3	0	14 7	1 6	90 3
Kerala	7 2	10 9	17 3	42 3	0	29 5	0	89 1
Madhya Pradesh	4 1	4 8	26 2	29 8	0 2	12 3	26 8	95 3
Maharashtra	14 6	19 5	33 6	28 4	0 1	4 3	13 7	80 1
Meghalaya	6 1	6 7	63 7	14 0	0 1	15 5	0	93 3
Orissa	3 6	5 7	15 3	45 9	0 1	9 6	23 4	87 2
Punjab	2 8	3 7	22 8	47 7	0	4 0	21 7	87 2
Rajasthan	9 2	12 7	26 9	39 5	0	13 4	7 4	96 2
Tamil Nadu	3 6	4 6	0	35 0	0	19 0	32 4	87 2
West Bengal	7 0	21 4	6 6	17 8	0 7	38 9	14 6	86 4
Delhi	4 6	43 4	14 6	13 5	0	13 6	14 7	78 6
India	7 1	10 8	17 6	33 9	0 1	16 3	21 1	89 0

[3] For Bangladesh and Bhutan figures are not available separately for rural energy So these are not discussed in the text However it is clear that in the case of Bhutan, all the rural energy requirement is met by biomass, principally fuelwood considering that 95% of the total energy is contributed by biomass In Bangladesh, crop residues play an important role

Based on this information, the salient features of the rural energy consumption pattern in India are summed up here

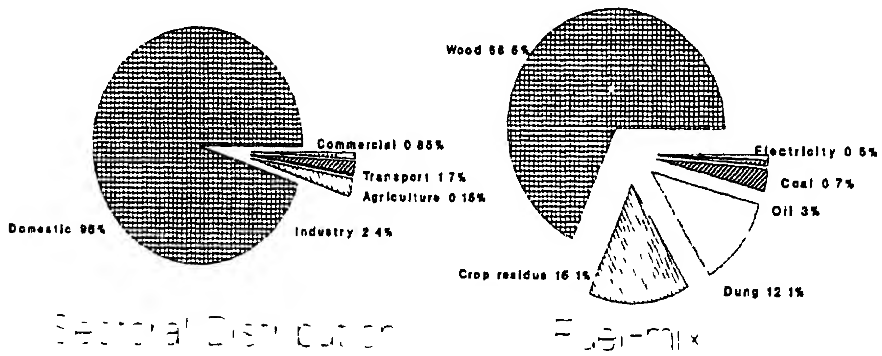
- Nearly 52% of the rural energy is contributed by fuelwood in the form of twigs and logs
- Dung and crop residues contribute 21% and 16% respectively for a total of 89% for the biomass fuels.
- 75% of the rural energy is consumed in domestic sector
- More than 90% of domestic energy goes into the single activity of cooking, making it the most important enduse in the rural areas
- Most of the biomass for energy use is collected at a 'zero private cost' But fuelwood trade in the form of headloads is going up, especially around semi-, peri-urban areas
- In agricultural sector, animate energy (human labour and animal draught power) is the primary source Irrigation is the main enduse for inanimate energy
- Kerosene is the most widely used commercial fuel, mainly for lighting but also cooking to some extent Kerosene contributes 7% of the total rural energy while the share of total commercial energy including kerosene is just 11%
- Commercial energy contributes to the total significantly only in industrialised, progressive states like Gujarat and Maharashtra.
- Energy use in industrial and transport sectors is marginal as these sectors are not yet well-developed in rural areas.
- Level of energy consumption is influenced by factors such as income, landholding, cattleholding, family size, seasonal variation, type of ecosystem, etc.

Nepal

Nepal is a country with little urbanisation and industrialisation Biomass fuels dominate the fuel-mix contributing 95.7% of the total energy (Pradhan and Amatya 1990). 95% of the energy is consumed in domestic sector, the rest of the sectors being marginal (Figure 4).

Figure 4

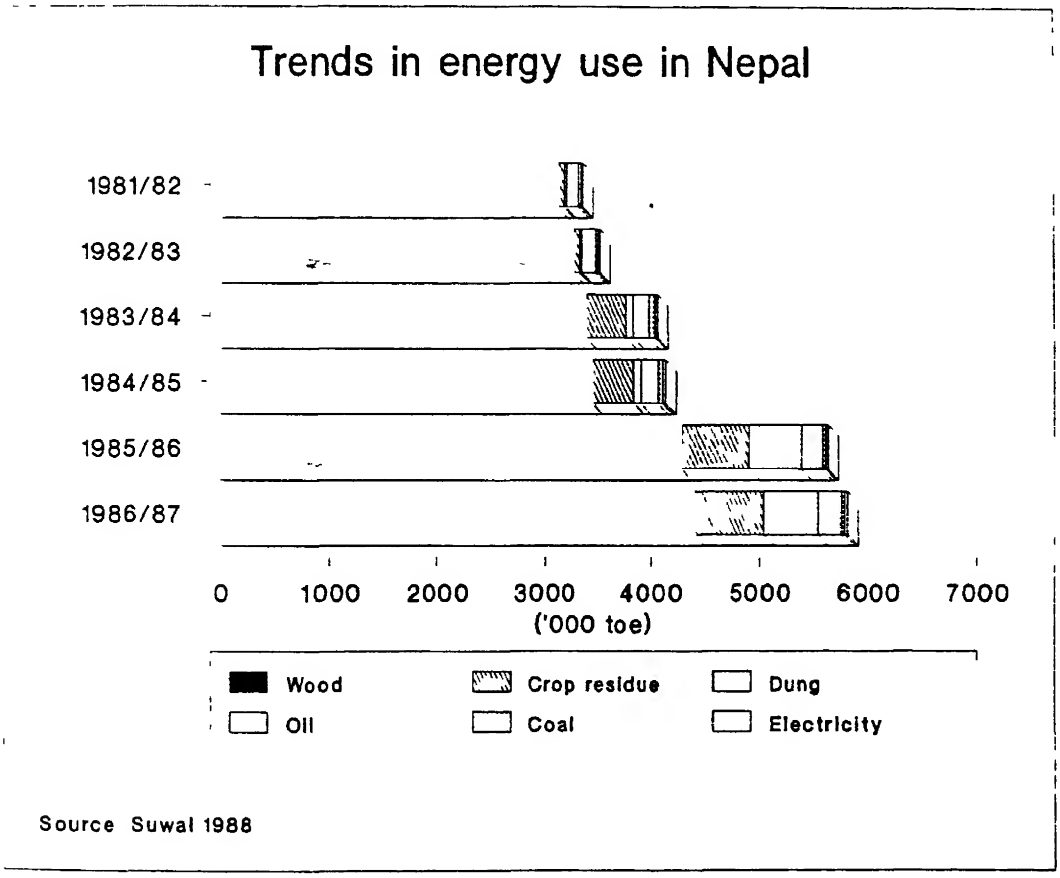
Energy use pattern in Nepal



Source Pradhan and Amatya 1990

The total consumption has been going up steadily, with the consumption of oil and electricity having nearly doubled during 1981-87 (Figure 5) But the overall relative proportion of fuels has more or less remained same and is not expected to alter in the near future (Suwal 1988) An interesting trend is the sharp increase in the consumption of non-wood biomass fuels – there has been a 10-fold increase in crop residue use and 20-fold in that of dung indicating relatively diminishing availability of fuelwood

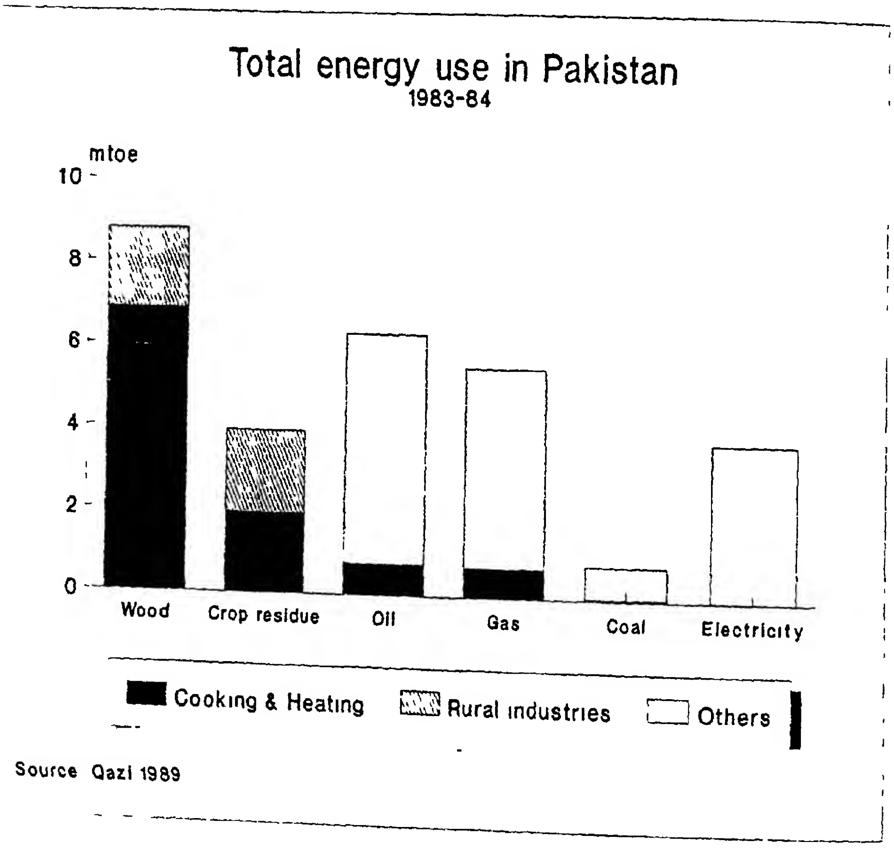
Figure 5



Pakistan

In the rural Pakistan, domestic and small industry are the main sectors (Qazi 1989). In the household sector, 91% of the energy is contributed by biofuels of which fuelwood alone accounts for 68%. For the enduse of cooking, 85% of energy comes from biomass while the rest are contributed by commercial fuels (Figure 6). 31% of the fuelwood and agricultural residue is used up in the rural industries.

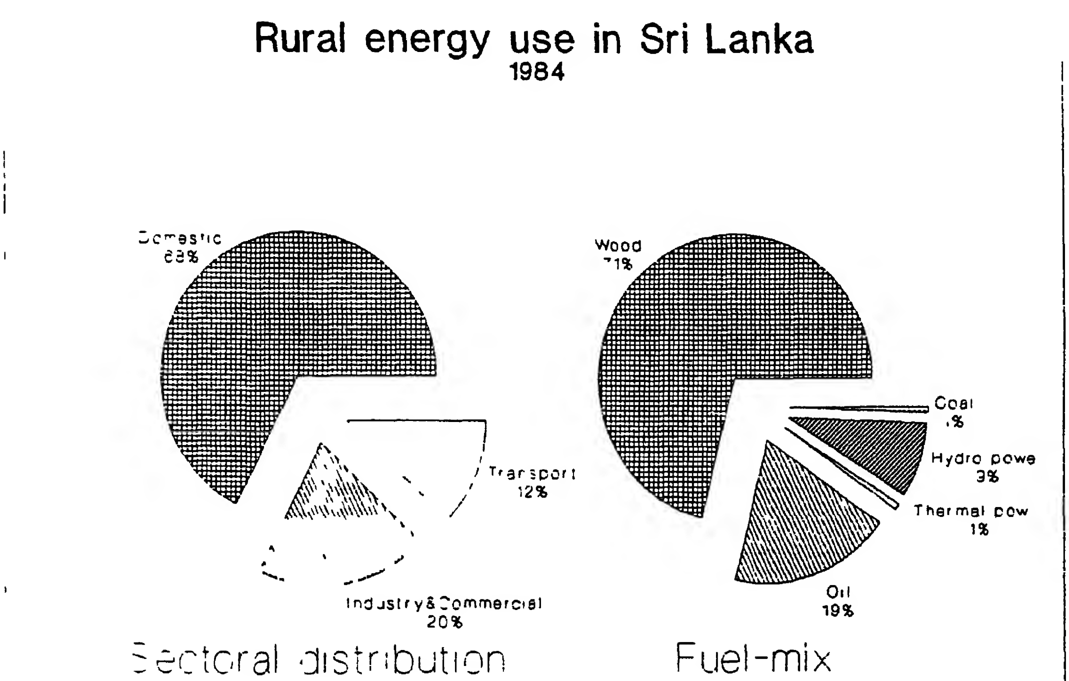
Figure 6



Sri Lanka

In the rural areas of the island nation of Sri Lanka, domestic sector is the most prominent as far as energy consumption is concerned (Nanayakkara 1986) Of the nearly 5 5 million tonnes of oil equivalent (mtoe) of energy consumed in the rural Sri Lanka in 1984, more than two-thirds was accounted for by the domestic sector while the industry, commercial and transport sectors consumed the rest Among the fuels, biomass, chiefly wood, contributed 71% while commercial fuels accounted for the rest Figure 7 provides the sectoral pattern as well as the fuel-mix in the rural areas

Figure 7



Source Nanayakkara 1986

Trends in supply-demand

Energy demand projection

With the steady increase in population, and mechanisation of agriculture and growth in rural industries, energy demand in rural areas is expected to go up steadily in the future However, given the low overall economic development and dismal purchasing power of the majority rural population, the energy use pattern is likely to be dominated by the biomass fuels for a long time to come

For instance, in India, the demand for biofuels in the domestic sector (all three put together) is expected to go up from 250 million tonnes per annum in 1990-91 to 333 million tonnes in 2009-10 (TERI 1991)[4]. At the same time the kerosene demand is likely to go up from 3 1 mt to 4 1 mt (Table 6)

Table 6: Trends in domestic energy demand by fuels (million tonne/year)

	1990-91	1994-95	1999-2000	2004-05	2009-10
Firewood	118 3	126 5	135 0	144 0	153 3
Agriculture residue	55 3	59 6	64 1	69 0	74.2
Dung	78.7	84 9	91 5	98 4	105 9
Kerosene	3 1	3.3	3 6	3 8	4 1

Energy supply

As far as supply options are concerned, biomass fuels, as already mentioned, will continue to hold sway in the rural areas. However, there are already indications that exploitation of biomass resources for fuel purposes is gradually becoming unsustainable from an ecological point of view For instance, deforestation rates in South Asia have been high throughout 70s and 80s, especially in countries like Nepal and Sri Lanka (Table 3) The fraction of forest and wood lands has declined over years The per capita availability of forest land has reduced significantly For instance, Bangladesh has a dismal 0 017 ha of forest per capita, Pakistan 0 027 ha, India 0 08 ha, Sri Lanka 0 102 ha and Nepal 0 13 ha Only Bhutan has a respectable figure of 1 87 ha per capita Thus, fuelwood availability has not matched the demand For instance, the sustainable fuelwood yield from India's forest and woodlands is just 39 mt compared to the demand of 120 mt (FAO 1989) The production of animal dung is about 80 mt per annum but the demand is going to be 100

[4] This assumes some penetration by renewable energy technologies and energy conservation measures In a business-as usual situation the demand will be much more

mt in 2004-05. However, this is assuming that all the dung produced would be used as fuel whereas the primary use of dung in India, indeed in most South Asian countries, is as fertilizer

The increased use of fuelwood and dung may have several negative manifestations as far as the society and environment are concerned

a) Even though the primary cause of deforestation is not the demand for fuelwood in the rural areas - major reasons are industrial and commercial demand, need for agricultural land, mining, large projects, etc - wherever the forests are receding, the fuelwood availability has diminished, which in turn results in the illegal felling for fuel

b) Faced with growing shortages, women and children are forced to travel longer distances and invest more time in collecting fuelwood, adding to their burden This is particularly stark in the Himalayan region where women have to actively participate in productive activities such as cultivation

c) As the biomass fuel availability goes down, poor households are likely to switch over to inferior fuels such as weeds leading to health and nutritional problems

d) Unsustainable extraction would lead to slower rate of natural regeneration

e) Lack of support from biomass resources such as dung and leaf litter could render the agriculture unproductive affecting the soil quality.

f) Scarcity of fuelwood could generate a market for headloads further exacerbating the problem of forest denudation

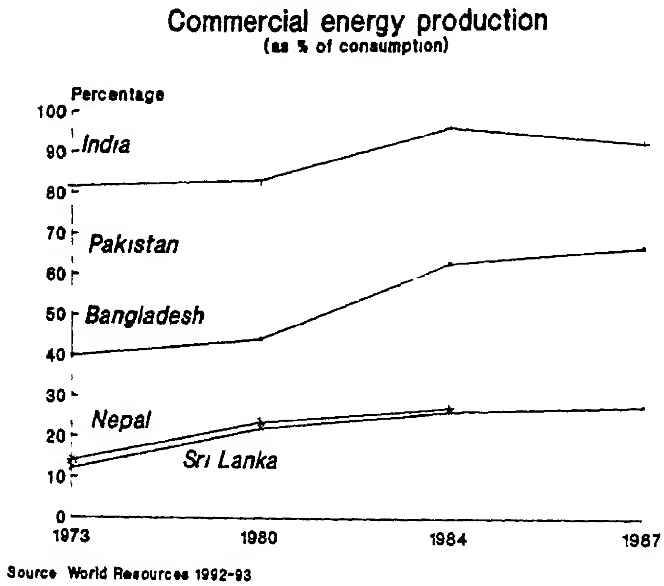
Therefore, it is clear that viable options should have to be developed to meet the rural energy requirements.

Development options

There are essentially four ways that can be adopted to meet the rural energy demand The possibilities that exist in these options are discussed here alongwith the measures that have already been taken

1 *Fuel substitution*: This would mean introducing the superior commercial fuels in the place of biomass fuels to meet various enduses (e g LPG and kerosene for cooking, electricity for lighting, diesel for irrigation, etc.). However, considering the commercial energy scenario, this option does not seem bright in the South Asian region. Most of the countries import a large proportion of commercial fuels placing heavy pressure on the balance-of-payments For instance, nearly 75% of the commercial energy is imported in Nepal and Sri Lanka (figure 8).

Figure 8



The import component has been going down slightly over years, but it is still significant In India also, though the import component is as little as 8%, in absolute terms the petroleum imports account for nearly 1/3 of the export earnings In Pakistan, the indigenous fossil fuel sources are expected to last, at an annual increase of 10% in consumption, for a short period only - oil reserves for 2 years, natural gas 16 years and coal 18 years (Noorani and Siddique, 1990)

Given this scenario, most of the commercial energy is likely to be consumed in other sectors like industry and transport This, coupled with the meagre purchasing power in the rural areas, puts a question mark over the fuel substitution possibilities

Rural electrification has been one of the most widespread programmes promoted For instance, in India, more than 82% of the villages are claimed to have been electrified till 1990-91. however, the impact of rural electrification on development needs to be studied in detail

2 *Energy augmentation*· This option explores the possibility of increasing the energy availability through energy plantations and afforestation of wastelands Attempts at this were initiated in the late 1970s in almost all the South Asian countries with the aid of multilateral agencies such as World Bank and UNDP While it is not known how most of these efforts contributed to the energy supply, according to available information, the rate of afforestation has not matched rate of deforestation For instance, between 1981-85, only in Bangladesh and Bhutan both the rates matched while in all others, deforestation was more than afforestation (Table 3) The imbalance was particularly sharp in Nepal and

Sri Lanka, incidently the countries with high deforestation rates In Pakistan just 10% of the targetted land has been afforested (Noorani and Siddique 1990) People's participation, choice of species are some of the aspects that needed lot of debate, according to the available information

3 *Energy conservation* This aims at making a more efficient use of the same fuel The two enduses that have scope for improved efficiency are cooking and irrigation In India, 8 35 million irrigation pumpsets have been energised by 1989-90 (TEDDY, 1992) However, more than 3 million pumpsets are still run on diesel and have a scope to be made more efficient by about 30% The major programme to enhance the fuel efficiency in cooking has been that of improved cookstoves (IC) By effecting design changes in the stoves, their heat utilisation factors and fuel efficiencies are improved The technology has an advantage of using locally available material and skills and can be spread in a decentralised fashion With this in view, large scale improved cookstove programmes were launched in most South Asian countries in the early 80s For instance, India itself has installed more than 14 million improved cookstoves by 1992-93 and is poised to disseminate more. Countries like Nepal, Sri Lanka and Bangladesh also disseminated ICs in large numbers In the beginning, most of the programmes had mixed results because of problems related to understanding the concept as well as the process of implementation An overall evaluation should come out before definite judgement could be pronounced on the success of the programmes

4 *Renewable energy technologies:* By using renewable sources such as biomass, wind and solar energy, energy supply could be augmented For instance, using dung in biogas plant, could provide fuel as well as fertilizer Thus renewable energy technologies (RETs) could provide a viable alternative to meet, at least partially, the energy requirement in rural areas Apart from being renewable in nature, RETs also have an advantage in that they can be installed as stand-alone systems even in remote and inaccessible areas without the infrastructural costs involved, for instance, with rural electrification And RETs can be used in a variety of activities such as cooking, lighting, water pumping, motive power, power generation, etc

In this background, India has launched a renewable energy programme in the early 80s and by 1992-93, installed a large number of RETs in all parts of the country Table 7 provides a list of RET installations in India

Table 7: RET installation in India (upto March 1993)

Biogas plants (family type)	17,63,133
Community/Institutional Biogas plants	1,009
Improved cookstoves	14,505,827
Gasifiers	9.5 MW
Solar cookers	2,88,028
PV street lighting systems	29,198
Water pumping systems	756
Community lighting & TV systems	784
Domestic lighting systems	14,594
Power plants	408kWp
Water pumping wind-mills	3,009
Small hydro power plants	94 MW
Integrated Rural energy Villages (Urjagram)	184

Source. Overview of Programmes, Ministry of Non-conventional Energy Sources, 1993

Among the RETs, biogas programme in the largest in terms of numbers crossing 1 7 million mark by 1992-93 The rest are mostly at a demonstration stage Some of the constraints and problems faced in the renewable energy programme in India are

a) The reach has been too small so far to make any real impact For instance, even the 1 7 million biogas plants installed in a decade represent only 1% of the total rural households in the country

b) Cost of installation in some RETs is very high compared to conventional energy sources making them unviable Presently, most of the programmes are run by the government with subsidies and if they have to assume marketability and make an impact on the energy scene, technological breakthroughs are necessary

c) Some of the programmes have not taken off properly due to problems associated with implementation process

In the other countries, too, RET programmes have been launched on different scales For instance, Pakistan has installed more than 4000 biogas plants, 18 solar power stations (390 kW), 4 solar water supply systems, 2 wind power stations and 4 wind pumps (Noorani and Siddique, 1990). Bangladesh installed more than 300 biogas plants and 100000 improved stoves and has a IV Plan (1991-1995) target of 1 6 million improved stoves, 5000 biogas plants, 30000 insulated box cookers, 4000 solar hot boxes, 5000 solar cookers and 25 photovoltaic power plants (50 kW) (Hasan, 1990)

However, it is clear that while RETs have immense potential, they still have to penetrate the rural areas in a major way

Strategies for energy development[5]

As far as meeting the energy requirements of the future is concerned, since biomass fuels will continue to dominate the fuel-mix and there is little possibility of fossil fuels replacing biofuels in a major way, any strategy aiming at energy development has, perforce, to be biomass-based Such strategies should not only optimise the energy availability for various enduses but also ensure environmental sustainability. This would mean a systematic attempt at rural energy planning At the macro level, several planning models are available for energy planning such as LEAP, TEESE, IMEEP, MARKAL, etc Some suggestions have been given here for energy planning as well as implementation

a) Planning exercises should be conducted in a decentralised fashion at microlevel Since a country is likely to have more than one ecosystem with different characteristics, macro planning is not likely to capture the basic differences, especially in large countries such as India and Pakistan.
b) Strategies to promote various alternatives such as conservation, supply augmentation, RET promotion, etc should not be devised in isolation but as an integral part of the decentralised planning This would help in matching the energy demand with supply in an optimal way
c) A lot of reform needs to be brought into the process of implementation as, often, all other things being equal, it is the implementation process that determines the success or failure of a programme As suggested in the following table, the orientation towards various aspects needs to given or different direction.

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[5] This is based largely on Indian experience and there could be different strategies for different countries depending on specific imperatives

Table 8: Planning and management

From	To
Centralised	Decentralised management
Revenue	Resource orientation
Production	Sustainability
Single	Multiple products
Large plans	Micro plans
Target	Process orientation
Unilateral	Participatory decision making
Punitive rules	Enabling rules
Control people	Facilitating people
Department	People's institutions
Assumed homogeneity	Recognised diversity

d) Appropriate institutional structures need to be built and inter-agency coordination ensured to bring about successful execution of the programmes

e) Thrust has to be put in proper training of officials involved in the rural energy planning and implementation

f) Efforts have to be stepped up in research and development to devise and improve the technologies that can make optimal use of biomass resources, e g wood gasifiers, briquettes, biogas plants, etc

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Urban Transport Planning and Implications for Energy Demand

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1. Introduction

1.1 Urbanization, including metropolitanisation, is a worldwide phenomenon, even an index of modern industrialization and development Over 40% of the world population is urban, and about 28% lives in cities with a population exceeding 0 1 million (m) In developed countries the urban population exceeds 70% By the year 2000, there would be about 400 cities having population exceeding 1m and 57 having population exceeding 5m each With the progressive growth of the urban centres, the requirements of mobility, both the number of trips as well as the average trip length, increase in quantity and complexity The availability of fast means of urban transportation in turn leads to further growth and spread of cities Mushroom growth of suburbs around large cities leads to the development of the suburban transportation arteries converging onto the city centres Further on, large number of people commute daily from townships located upto say, 50 km or even 100 km away, to the metropolitan cities for work, education, trade etc As a result, the "urban", "suburban" and "commuter" streams of traffic tend to merge with each other, and these terms are frequently used interchangeably Here, the term "urban transport" (UT) is taken to cover the full spectrum of the urban/suburban/commuter passenger traffic

In this paper, broad aspects of urban transportation and its energy implications have been dealt with, and the data of the Indian metropolitan cities has been used to illustrate the general situation in South East Asia

2 An overview of urban transportation

Development

2 1 As the urban centres grew, so also the common means of UT evolved from walking and cycling into manually/animal driven hired vehicles, private automotive two-wheelers (ATW) and cars, paratransit automotive road vehicles (3 wheelers, taxis) and common carrier road (buses) and rail-based (LRT, mass rapid transit) services So also developed, grade separated arterial roads, surface, elevated and

underground ("metros") railroads, and traffic controls on the roads (dividers, signals, subways etc) These developments are very much dependent on the characteristics of the city, its population and their working and economic conditions For example, in developed countries, LRTs and metros are being provided in cities having less than 0 1m population, but in developing countries even cities with 5 to 10m populations may not be able to afford these and much of the other costly infrastructure for UT

2.2 Road transportation contributes most to the UT because of its flexibility, propulsion range(walking and cycling to cars and buses), modularity and accessibility No wonder, the public urban transport largely centres around the bus services There is a wide range of vehicles covered under the term "bus", for example, the standard largesized bus, mini-buses, tempos, double-deckers, buses with trailers etc

2.3 Rail-based transit systems have the advantages of simple basic engineering, guided transport, exclusive right-of-way (R/W), and compared with road public transport systems, of lower energy consumption (steel to steel rolling friction is only about 1/10th that of a rubber tyre on a concrete road), very low pollution particularly with electrified systems, much lower accident rate and a smoother and more comfortable ride But their flexibility being lower, only higher traffic densities can justify their provision, and due to the lower adhesion at the rail-wheel contact, longer braking distances and easier gradients are necessary

LRT (light rail transit) and HRT/RRT (heavy/rapid rail transit) are distinguished basically by an exclusive R/W for the latter and the concomitant high level platforms, larger trains and fully automatic failsafe controls

Categories

2.4 There are various ways of categorizing the urban transport systems, such as,

A By the usage category

- private - walking, cycling, ATW, cars
- public -

(a) hired (i e demand responsive), also called Paratransit, Intermediate or Secondary For example, cycle rickshaws, 3-wheelers, chartered buses

(b) common carrier (i e fixed routes and schedules), also called Transit or Mass Transit For example, street transit (bus, trolley bus, streetcar or tram), Semi-rapid transit (bus, LRT), Rapid transit (HRT)

B <u>By the R/W category</u>

- on surface, with mixed traffic
- separated longitudinally
- grade separated, exclusive - elevated or underground

C <u>By the important technical features</u>

- support system (road, rail, waterway)
- guidance system (steered, guided/tracked)
- propulsion system (animal, manual, petrol, diesel, electric)
- control system

D <u>By the type of service</u>

- short haul (urban), city transit (suburban), regional transit
- "local" or "express" services
- all day or "peakhour" or "special" services

E <u>Whether a system is fixed or variable in time and space</u>

<u>Capacities</u>

2 5 Obviously, the actual capacity of any UT system is highly specific to the local operating (halts, R/W, congestion), traffic, pricing and control conditions Therefore, the following figures are mostly indicative of the relative capacity of different modes

	Max. Capacity	# of people carried/lane or track/hour
Walking	5000-6000 people/metre of walking width in 'corridors', and about 50% of this in less orderly street sidewalks	
ATW	2	5000-10000
Car	4	5000-10000
Conventional bus	52	10000-30000
LRT	300-500	15000-35000
HRT	1000-3000	40000-60000

Average speeds too vary with the road and operating conditions, and may range from 10-20 kmph for public road transit, to 15-30 kmph for LRT and 25-40 kmph for HRT

<u>Planning</u>

2.6 UT planning consists of a series of interconnected steps and is a multilevel process with a multicriteria (social, economic, technical) approach, by which optimum solutions can be formulated to the complex problem of UT For its theoretical framework, three concepts could be employed (i) of land use - transportation interaction and alternative 'landuse-transport' strategies, (ii) of derived travel demand, and (iii) of impedence minimisation The basic approach would need to be very different in the resource-starved developing countries from that in the affluent developed countries At present, while the developing countries are trying somehow to match transportation accessibility with demand ("supply augmentation"), the developed countries are trying to correlate the demand to the land use ("management and manipulation of demand" through direct traffic engineering and restraint methods or indirect and non-transport strategies such as staggering of working hours, restricting vehicular movement away from crowded city centres, and integrated land use development)

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2.7 Urban travel as a derived demand is continuously rising, because of the increasing i) population, ii) mobility rates (avg no of trips/person/day) and iii) trip length An analysis of trip generation, trip distribution, modal split and trip assignment based on the origin-destination data and GIS (geographical information system) is the key towards optimizing the urban transportation provision The burgeoning socioeconomic activities, liberalization of economies and rising GDP are further challenges, encourage as these do the proliferation of personal transport (cars and ATW) For example, the number of cars/1000 population is only 2 in India (but more than 50 in Delhi), 11 in Malaysia and 70 in Thailand In Delhi, both the mobility rate and the average trip length have nearly doubled since 1969, increasing the travel demand per person to 4 times[1]

2.8 A sound UT policy would enhance capacity for mobility but conserve energy, control pollution, and enhance safety by an optimum modal usage, fiscal and pricing policies, control of external factors such as land use, housing market, household structure and income employment centres, etc and through non-transport alternatives like staggered working hours, telecommunication facility and appropriate urban design, and above all, by flexibility and midterm correctability of the solutions

3. UT scene in India

3.1 The problems of urban transportation in India are typically those of the developing countries with high population growth rates, fast growing highly congested urban conglomerations, burgeoning UT demand, and severe resource constraints

	1951	**1991**	**2000 (forecast)**
Total Population	362 million	844 million	About 1 14 billion
Urban Population	62 4 million (17 3%)	217 2 million (25 7%)	(35 5%)
No of Metropolitan cities (> 1 million population)	5	23	41

65% of India's urban population lives in 300 cities having over 0 1 million population each Calcutta has a population density 19 times that of London and 9 times that of New York

3.2 Except in Bombay, Calcutta, and Madras, which were provided with a surface railbased HRT in pre-independence days and which has been progressively augmented and extended after Independence, the basic urban transportation consists of public and private road transport modes The city master plans have paid little attention towards simultaneous planning of mass rapid transit Delhi has been very negligent in this regard Its road transport infrastructure capacity is enhanced willy nilly after the demand has well appeared As a result, Delhi with 20% of its land under roads has an inferior and costlier UT system than Bombay with only 7% area under roads Delhi has more automotive road vehicles than Bombay, Calcutta, and Madras put together

	No. of vehicles (million)	**No. of persons/vehicles**
Delhi	1 99	5
Bombay	0 65	24
Calcutta	0 63	45
Madras	0 48	55

3.3 In India, UT Planning in various metropolitan cities is passing through the typical phases leading to a progressively deteriorating situation -

- The Longterm Plans which give fairly correct predictions but the solutions proposed can hardly be implemented
- Incremental Improvement Plans, do manage to secure some success because of smaller project sizes, and
- Sectoral Improvement Plans, with road & railway authorities acting independently in their respective domains But with the Railways having given up UT planning because of its uneconomic nature, the pressure on road

based solutions has enhanced while it should have reduced The loud talk for having an integrated urban metropolitan transport authority in each main city has little to show on ground so far

3.4 The overall position of motorized road vehicles in India in the global perspective is indicative of its underdevelopment It has 0 6% of world's 35 million cars, 0 8% of its 12 million trucks and 13% of its 13 million ATW, i e 3 0%of the total 60 million vehicles, as against 1/6th of the world's population As a result of highly inadequate railbased UT, and low affordability of personal motorized vehicles, particularly cars, there is a profusion of cycles (about 2m in Delhi), cyclerickshaw, and sorts of motorized 2 and 3 wheelers, apart from buses for urban transport Freight transport within urban conglomerations suffers from similar deficiencies All this combined with congested and illmaintained roads, heavy trespassing, encroached footpaths leading to heavy pedestrian traffic on the roads, absence of separate cycle ways (as existing in Beijing), reduces the average speed of movement to only 5-10 kmph is busy city centres and going upto 20-25 kmph in more open areas with better roads, less of slow traffic and trespassing Mixed R/W is the norm and grade separations are the exceptions

3.5 A 16 km long 'metro' is under construction in Calcutta 10 km of it was opened in 1986 The progress is very slow mainly because of the lack of funding Only about 45,000 journeys are performed daily on the opened section, mainly because of the 'high' fare (Rs 2 i e 6 cents US upto 5 km) On the suburban railways in Bombay, Calcutta and elsewhere in India, on a monthly season ticket, a single journey of 5km would cost only about Rs 0 40 (i e 1 5$US) The capacity of a large section of the people to pay is a major constraint to the construction of new railbased high investment systems

3.6 Bombay has the best rail-road integrated UT system About 4 6m journeys are performed daily by rail, with average lead of 20-25km, and about the same number by buses with average lead of 6-7km 9 coach suburban trains carry upto 3500 commuters - an incredible over 10 people/metre square of floor area, in peak hours

This low cost UT system is the backbone of Bombay's existence No wonder, the State Government gave pride of place to providing a similar MRTS in New Bombay also, even contributing 2/3rd of its cost

3.7 Delhi is an opposite case Its about 2 million motorized passenger road vehicles consist of 71 5% ATW, 24 3%% cars and only 4 2% buses, autos and taxis Number of vehicles per km of road length has increased from 26 in 1972 to 97 in 1991 Buses are the backbone of Delhi's public transport 'Category I' buses (free access, i e fixed routes and schedules) log average about 200 km/day and 'Category II' buses (restricted access e g charted buses) about 170 km/day Average occupancy of the former is 60-65 and of latter 35-40 i e pass-km/day of 12000 and 6500 respectively

3.10 Delhi MRTS Thirty four reports have so far been produced for an MRTS (mass rapid transit system) for Delhi over last 25 years Fortunately, the last report by M/s RITES has been approved by the government, though the issue of financing could still prove its Achilles' Heel It envisages construction of 27 km of 'metro', 140 km of dedicated 'surface' rail corridor and 17 5 km of dedicated busway, costing total Rs 53 8 billion (1989 prices) The analysis shows a direct saving in petrol and diesel worth Rs 2 48 billion/yr, and a further Rs 4 63 billion/yr because of resultant decongestion of roads by 2010 (taking 20 years as construction schedule) Salient data for the proposed MRTS is given below

	1981	1993	2000	2005	2011	2021
Passenger trips/day (m)		10 4	15 8	17 6	20 8	27 4
Per capita trips rate/day		1 15	1 33			
No of trips by mass transport (m)	3 8	7 2	12 4 (78%)	14 3 (81%)	17 6 (84 6%)	24 6 (90%)
No of trips by private (fast) transport (m)	0 6	2 0	2 25	2 1	2 0	1 6
No of trips by private (slow) transport (m)	1 2	1 2	1 2	1 2	1 2	1 3

Average trip length for Delhi has been assumed at 11 5 km for buses and 13 4 km for private transport in 1993 The passenger km will grow from 110 4 m in 1993 to 355 37 m i e 3 27 times by 2021 At the end of phase I of MRTS (year 2001), rail would handle 3 1 m trips/day (23 7 m PKM) and road the balance 125 1 PKM, thus needing about 12,500 buses Thereafter, the bus load would remain constant and rail will take the full incremental load

4. ISSUES AND CONSTRAINTS IN UT PLANNING

4.1 Automotive dominated systems are often criticized for excessive energy requirement, pollution and accidents By their inherent flexibility, these encourage urban sprawl, leading to hardships to the poorer sections, downgrading, of the public transport system and heavy investments in road infrastructure However, personal vehicles do offer speed, flexibility, reliability and comfort and are bound to increase with improvements in socio-economic conditions Rail based public transport systems require much less energy, and cause less pollution, accidents and congestion A study has indicated that for a city with 1m population at least 35% of journeys should be performed by public transport and for 9m or higher population, 75% Primarily UT policy has to judiciously balance the private and public benefits and costs Most importantly, UT system of a city should be developed as one integrated system, with the authorities providing for the optimum infrastructure facilities and pricing, fiscal and regulatory conditions which gives priority to public over private transport, and minimizes energy consumption, pollution, accidents, discomfort and time loss

4.2 Common problems encountered in implementing a coordinated UT system are multiplicity of authorities, inadequate supply and poor quality of public transport services, little interaction between landuse policies and transport planning, and an inappropriate pricing regime The issue of resource mobilization is the single most vital cause for the poor public transport systems in developing countries In Asian metropolitan cities, the slum and homeless population have very low paying capacity The fare elasticity is —0 3 to —0 75 where both rail and bus services compete (In Calcutta Metro, increase in fare from Rs 1 to Rs 2 per journey resulted

in a 40% fall in ridership Compare this with the minimum ticket of Rs 36 to Rs 40 in Paris and London metros, which still do not recover their operating costs) to —0 1 in Delhi

4.3 Inspite of the higher unit cost/Passenger-km, higher energy costs, pollution, accidents, and time costs, in India, road transportation continues to be the means, for bulk of the urban movements This is so because the social action and investments for railbased MRTS are lacking and road vehicles, private or public, need only piecemeal investments Roughly, the direct cost/passenger-km is Rs 2 for car, Rs 0 80 for ATW, Rs 1 5 for a hired paratransit vehicle, Rs 0 20 for a bus or for an HRT (surface based) The congestion, parking, policing and signalling costs would be extra, as also pollution and accident costs To what extent full infrastructure costs are paid by the road transport is also doubtful

4.4 In the poorer developing countries, the role of the non-motorized UT too is important but such paratransit modes are ignored and neglected in the planning process Cycle rickshaws are the most important modes of UT in Kanpur and Patna cities Similarly, provisioning and upkeep of footpaths and cyclepaths is largely ignored The planners even ignore the major contributions being made in the overall urban transporation by such means

4.5 Pleading for a "sustainable" UT system, I Serageldin, in his address to the 50th Congress of the International Union of Public Transport in Sydney in May 1955, had dwelt on the hazards of the unlimited growth of road vehicles, indicating that these include consumption of 60% of natural rubber production, 20% of steel and 10% of aluminum Over 0 5m people die every year in world's road accidents, and in Mexico alone, 11 2m working days are lost annually because of transport based air pollution [7] The railbased UT system sells not only transportation but also clean air, safety, faster mobility and better quality of life In the US experience, for equal quantum of traffic, road transport — in relation to rail transport — needs 3-5 times more fuel 4 times more pollution if railway traction is diesel, and 40 times of it is

electric, 50 times more accident deaths, and more land space and causes more congestion and stress [9]

4.6 As stated by Gordon Porter in his article on "Planning and Funding Underpin Urban Rail Development" [8], in the developed world most major countries have well developed transport infrastructure with modern highways and road and rail based public transport But the developing countries tend to have one or more dominant, large cities with growth rates unimagined in the West The political and, professional groups from the developing countries aspire to replicate the 'metro' and the LRT systems of the West in their countries (ignoring the much more affordale systems like Bombay's railways) and hence fail mainly on the financial logic In the Indian experience, we can not afford metres HRTs on any large scale and the 'surface' rail MRTs, with complementary bus services, at affordable levels of service (usage density, etc) are our best bet

4.7 Environmental pollution is becoming a major determinant factor for selecting an appropriate UT system An idea of the air pollutant load in kg of emissions/1000 vehicle-km, with the CO load in brackets, is given below

Bus, truck	(diesel)	38 (12 7)
Car	(diesel)	3 2 (1 1)
Car	(petrol)	50 (40)
3 wheeler	(Petrol)	36 (25 5)
2 wheeler	(petrol)	27 3 (17)

4.8 Road accidents are becoming the next important determinant for a renaissance of rail transportation in the West In 1991, in India as a whole, 60,094 people died in road accidents from the 0 29m road accidents (in railway the number of deaths is less than 1% of this) Of course, in urban conditions, the accident rate/1000 vehicles does tend to reduce with high vehicle growth rate, accompanied as it is with reduced speeds and improvements in road signalling, grade separations and other such inputs including stricter enforcement of traffic rules

5. The energy demand for UT

5.1 Unit energy demand (per passenger-km) of various motorized and rail based UT modes is a widely varying phenomenon as it depends on a host of factors, particularly the level of occupancy, operating and road conditions, apart from the technological and vehicle maintenance factors Here, only indicative data is being given in order to highlight the implications for the energy demand Typical values of the total energy intensity of urban transport modes are as under

	Car	ATW	Bus	HRT	LRT
Vehicle capacity (number)	4	2	52	75	-
Occupancy (number)	2	1 5	52	120	-
Actual energy (kWh)/passenger-km [2]	1 12	0 29	0 12	0 09	-
kWh/passenger-km [5]	0 83-0 17	-	0 28-0 024	0 18-0 01	0 34-0 01

Roughly, private modes (car, ATW) consume 3-20 times the specific energy of the mass transit systems Another estimate indicates an energy demand/passenger-km of 0 68 kWh by bus and 0 17 kWh by HRT (surface based) Energy demand of a 'metro' railway increases sharply on account of ventilation, lighting, and other ancillary loads Energy consumption of rail MRTs is also highly sensitive to the occupancy levels, as well as seen below

5.2 'Suburban' railways in Bombay run on 1500V DC traction and in Calcutta and Madras on 25 kV AC traction Otherwise, these are similar 'surface' systems with simple EMU stock with wide doorways but w/o doors except that Bombay and Calcutta are broad gauge (1576mm) and Madras is largely meter gauge The effect of 'occupancy' is clearly illustrated by the wide range of energy consumption (kWh/passenger-km) in these systems Calcutta Metro is a case by itself, 750 V

Suburban:

	Bombay		Calcutta		Madras	
	A	B	A	B	A	B
No of passengers (x 10^3)	1 978 933	1 865 776	456,695	411 686	67 067	65,789
Passenger-km (x 10^3)	43 061 990	41 210 784	15,571 073	14 577 892	849 677	888 689
Power consumption for traction (incl train lighting) (x 10^3 kWh)	425,963	415,998	295 235	292 599	40 538	42,617
kWh/passenger-km	0 010	0 010	0 019	0 02	0 048	0 048

A = 199192 B = 1992-93

Calcutta Metro In 1991-92, 24 144m passengers travelled, logging about 150m passenger-km Energy consumption was

Traction	6 62m kWh	i e 0 044 kWh/passenger-km
Non-traction	19 39m kWh	i e 0 129 kwh/passenger-km
Total		0 173 kwh/passenger-km

In 1992-93, because the fares were raised, number of passengers fell by 34 3%, but total energy consumption was hardly affected Hence, energy demand/passenger-km escalated sharply

Traction	0 063 kWh/passenger-km
Non-traction	0 200 kWh/passenger-km
	0 263 kWh/passenger-km i e an increase of 52% over 1991-92.

This too confirms that energy consumption/passenger-km is highly dependent on the occupation density

Thus, overall, a range of 0.01 to 0 263 kWh/passenger-km is being experienced on the Indian Railway itself. Even on the 'suburban' system itself, a range of 0 010 to 0 048 is experienced

5.3 Delhi experience for road traffic is illustrated by the data (average values) collected from M/s RITES

Category I buses	run 3 8km/litre diesel for 200km and 12000 passenger-km/day	i e 4.33 ml/passenger-km
Category II buses	run 3 8km/litre diesel for 170km and 6500 passenger-km/day	i e 6 94 ml/passenger-km
Taxis	run 10km/litre petrol for 80km and 12 passenger-km/day	i e 66 7 ml/passenger-km
3-wheelers	run 16km/litre petrol for 80km and 112 passenger-km/day	i e 44 6 ml/passenger-km
ATW	run 25km/litre petrol for 25km and 32 5 passenger-km/day	i e 30 8 ml/passenger-km
Cars, etc	run 10 km/litre petrol for 40km and 64 passenger-km/day	i e 62 5 ml/passenger-km

Taking average of all private vehicles (as their fuel/passenger-km values lie in a close range) -

	Bus (category I)	Bus (category II)	Private vehicles
Passenger-km/day	12000	6500	49
Average occupancy	61 4	38	1 4
Fuel/vehicle-day (litre)	52 (diesel)	45 (diesel)	2 26 (petrol)
Fuel/passenger-km (ml)	4 33 (diesel)	6 94	46 3 (petrol)
Fuel/passenger-km (kWh)	0 016	0 025	0 170
Approx Passenger-km (million)	70	14 2	265
Approx total fuel consumption (kl)	30	10	123

Energy consumption in kWh has been derived by equating 3 67 kWh_e = 1 litre diesel/petrol

It maybe seen from para 5 1, that energy/passenger-km values for bus and private vehicles lie at the lower end of the range of values indicated therein This maybe because bus occupancy values are high and most of the private vehicles have a low power rating compared with the average cars in Western countries where much higher speeds are common on the roads

It maybe concluded that for the average conditions, private vehicles consume 8-9 times fuel of the buses on passenger-km basis, number of private vehicles would be 200 times that of buses for a given passenger-km load, and private vehicles have to run about 35 times the distance of buses for a given passenger-km load

5.4 On the above basis, and from para 4 7, the air pollution caused by private vehicles will be roughly equal to the occupancy ratio of bus to the private vehicle i e

about 30-50 times of the bus as the emissions for vehicle-km are of similar order, partly because diesel fuel emits only 1/7th the pollutants emitted by the same quantity of petrol fuel It is obvious that the accidents too would be less with buses than with private vehicles It is also seen that for the same traffic level, private vehicles on an average will need over 10 times the road space of the buses

5.5 Fuel consumption by road vehicles is quite sensitive to the quality of the road surface also, as maybe seen from one set of values [2]

Unevenness index (mm/km)	Fuel consumption (l/100 km)		
	Bus (double lane, rolling terrain)	Premier car	Ambassador car
2,000	8 1	6 8	7 5
16,000	9 8	9 3	8 3

5.6 Conventional buses in India use the truck chassis which is designed for 10 2t axleload (but providing for heavy overloading in practice) and speeds upto 60 kmph But, even with 100-120 passengers, the actual axleload in buses will not exceed 6-7t Properly designed 'urban' buses will save at least 10% in fuel consumption and upto half in air pollution [2] These buses would also have lower footboard level and wider doorways for easier and faster entry/exit

5.7 On the basis of 3 67 kWhe = 1 l oil, energy consumption/passenger-km in rail transport will be about this same in case of 'surface' HRT as the buses, both running at high occupancy rates The energy consumption, however, in case of a 'metro' could be very much higher, because nontraction energy demand could even be higher than the traction energy demand However, in case the electrical energy is produced as hydropower, then 1 lit ≈ 10 kWhe and rail transport could be much more energy efficient upto 2 5-3 times

6. THE ENERGY ISSUES AND IMPLICATIONS

6.1 Important factors influencing energy consumption in UT maybe summed up as

i) Vehicle characteristics - e g technology, design, capacity and utilization, performance, the type of fuel

ii) R/W characteristics - e g guidance and support systems, grade separation, lane and direction separation

iii) Operational characteristics - e g private or public, scheduling, status spacing and halts, operating regime, braking system, infrastructure and traffic control conditions

Energy efficiency = 1/unit energy consumption Out of the four most significant units, viz , kWh/vehicle-km , or gross t-km, or space-km (i e offered service), or passenger-km (utilized service), obviously, the last one i e kWh/passenger-km is the one of most concern

'Net' energy consumption should cover not only the energy used up directly by the vehicle but also by the supporting transport installations and functions 'Gross' energy is the energy utilized to produce the 'net' energy

6.2 Energy usage has to be evaluated along with the vital qualifying factors of i) domestic availability, and ii) its side effects, mainly environmental pollution In India, total reserves of coal are estimated at 193 8 billion tonnes, but of petroleum at only 5 32 bt Even though, India's per capita energy consumption is only 337 kg oil equivalent (1991) - including significant component of non-commercial energy - as against 9390, 7681, 3854, 5211, 2262 kg oil equivalent respectively in Canada, USA, UK France, Australia and South Africa, it is reeling under the burden of the forex expenditure on oil imports - that too when world oil prices are low Obviously, the energy-poor and resource-poor developing countries have to think of very different solutions to their UT problems from those applied in the developed world Per capita energy consumption is 602, 517, 279 and 243 kg oil equivalent respectively in China, Zimbabwe, Indonesia and Pakistan On consideration of air pollution, the consumption of petrol must be minimized over diesel, and of both

petrol and diesel over electricity based systems. Incidentally, for a country like India, both considerations lead to similar conclusions - to minimize use of private transport and encourage use of rail based 'surface'MRTS wherever the traffic density justifies it.

6.3 Thus, energy implications can be determined only of the UT transportation system as a whole and it is a complex and situation-specific exercise. Improvements in vehicle design, weight and controls and in road condition and traffic controls alone may reduce the fuel consumption to as little as half Narrow roads, poor geometrics, ill-maintained surface, heavy trespassing, unrestrained mixture of slow and fast traffic, inadequate provision for and separation of pedestrians and cyclists, and resultant reduction in average speeds with need to frequently brake the vehicles could double the specific energy consumption Varying occupancy ratios alone can half or double the energy consumption/passenger-km Therefore, a host of factors need to be considered while determining the likely energy consumption in any UT scenario Approximate cost of energy in urban travel, taking the present Indian conditions, say petrol at Rs 16/l, diesel at Rs 6/l, and electrical energy at Rs 2 50/l, for different modes, per passenger-km would be as under

Rail-based	- suburban	Rs 0 025 at Bombay, 0 05 at Calcutta, 0 12 at Madras
	- metro	Rs 0 43 (1991-92) to 0 65 (1992-93)
Buses		Rs 0.026 to 0 042 (Delhi)
Taxis, Cars		Rs 1
ATW		Rs 0 5

It is apparent, that the preferred choices would remain similar on all major considerations - of energy consumption, domestic availability, air pollution and costs

6.5 To sum up, following broad guidelines maybe followed in order to minimize the energy consumption and its adverse side effects in respect of urban transport systems

- Empower and encourage the pedestrians by ensuring adequate, clear and wellmaintained footpaths, and the cyclists by cycle paths and facilities for crossing major road intersections Pay greater attention to the design and functioning of paratransit modes such as cycle rickshaws, 3 wheelers and taxis
- Encourage public transport over private transport, and rail based MRTS over road based ones The use of metros should be kept to the minimum unavoidable stretches and 'surface' (including 'elevated') rail systems should be preferred
- Encourage technologies, vehicle designs and sizes which would minimize energy consumption/passenger-km
- Ensure R/W, minimize trespassing, mixing of slow and fast traffic, and heavy congestion
- Ensure proper maintenance and design of roads, maximum grade separation and facility for movement at intersections, optimum signalling and traffic controls
- Integrated UT authorities must be in position Secondly, this financial arrangements for heavy investments in public transport systems must be made available as finally, these are the least cost solutions, both socially and to the users
- Optimum vehicle occupancy should be the cornerstone of UT policy

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Industrial Energy Conservation

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Training Programme
on Energy Planning
for South Asian Countries

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INDUSTRIAL ENERGY CONSERVATION

Introduction

Why is energy conservation important ? The simplest answer is that it makes a firm more profitable By practising good energy management through a well structured and organised company plan, management and employees become more aware of how energy is being used, of the actual costs of energy and of the methods and equipment that can be used to control and reduce energy waste

Energy conservation does not mean having to do without energy or having energy supplies curtailed Energy conservation means reducing or eliminating energy waste throughout the plant so that the same level of goods or services can be provided with less energy (or of course the consumption of the same amount of energy to provide an expanded level of goods or services).

The effective use of energy, which is simply one resource used by a plan to make goods, is known as "energy management". Energy management is a disciplined activity, organised for the more efficient use of energy without reducing production levels or lowering product quality, safety or environmental standards The principle underlying all energy management must be cost effectiveness· energy conservation should only be practised to the extent that it can be justified in normal commercial and financial terms, like any other activity or investment. Energy management therefore requires both technical and financial evaluations.

Even more important, however, energy management requires a logical and comprehensive management approach Experience shows that energy savings are only significant and long-lasting when they are achieved as part of an overall plant energy management is required to identify and to realise the full potential savings.

It is apparent that many companies and plants have not taken the trouble to identify even simple energy conservation measures with short payback periods, and many who have identified such opportunities fail to implement them. Many studies show that the main barriers to action on energy conservation are typically:

- lack of knowledge of what is technically possible
- inappropriate financial analysis methods
- management attitudes to energy efficiency

The greatest successes generally occur at companies where management supports an integrated energy management programme and is seen to support it.

What are the specific benefits achievable through energy management ? There are often benefits both to the national economy and to the plant itself. At the national level, for example:

- immediate results - most conservation projects in manufacturing plants can be implemented within a year or so, offering faster benefits than high cost supply side activities such as the construction of new power plants or coal mines
- reduced load shedding - energy conservation measures can reduce the rate of demand growth, reducing the need for load shedding in electricity and gas supply systems
- lower energy imports - where energy supplies include imported oil, gas or coal, energy conservation can contribute in the short term to reduce imports
- lower foreign exchange needs - these follow directly from lower energy imports
- use of local equipment - often much of the equipment needed to implement conservation projects is made locally, thus encouraging local manufacturers.
- job creation - through the increased use of local equipment and a greater demand for energy-efficiency related services, conservation can contribute to job creation and to increasing the skills of the local workforce
- lower inflation - if firms are able to cut product prices or at least to moderate the rate of price increases, this will contribute to keeping inflation lower

At the plant level, benefits include:

- lower production costs and higher profits - energy costs can often represent a significant proportion of overall manufacturing costs' energy cost savings are thus a direct contribution to company profits and can be significant for energy intensive industries.
- better competitive position - firms achieving savings in energy costs are in a position to cut product costs and thus improve their competitive position against other domestic firms or in export markets.
- improved ability to withstand future energy cost increases or energy curtailments.
- improvements in productivity - energy management programmes can help identify productivity improvement and cost reduction opportunities that may relate to areas other than energy. Because energy management incorporates many disciplines (e g engineering, management, human relations), development of energy management programmes often results in improved utilisation of other resources such as raw materials and manpower.
- environmental benefits - saving energy almost always leads to lower emissions from manufacturing plants (e g. less smoke, less production of sulphur dioxide, lower NO_x emissions)

The potential benefits of good energy management are of course entirely dependent on the nature of the plant concerned. Energy intensities - the amount of energy consumed per unit of output - vary widely depending on the product in question, the type of manufacturing process, the type of fuel, age of equipment, size of the plant and operating practices However, savings for a plant which is starting an energy management programme are often 20 to 30 percent of present energy consumption, and even more in many cases. For most firms, energy conservation makes very good business sense

The Energy Management Approach

Where to start

How does a company begin to address the problem of controlling energy consumption and costs ? The answer will depend to some extent on the company concerned - its organisation, management philosophy, etc. Some questions that should be asked at an early stage include the following:

- the value of energy consumed
- energy cost as a percentage of total production costs
- who in the company currently looks at, or records or evaluates, energy consumption and costs
- the size of the company (number of employees, departments, site area)
- how many different products are made
- how diverse is the energy consuming equipment
- with the existing company organisation, how best can energy consumption be monitored in different areas or departments
- costs of additional meters
- what are the potential savings
- how do potential savings compare with current profits

There are many ways to approach energy management but two points are extremely important

- top management must be fully committed to controlling energy costs
- the appropriate organisation must be set up to implement, and be accountable for, the energy management programme.

The overall approach is illustrated in the Figure, showing the different elements which make up a total management programme for a plant. The main elements are discussed in subsequent pages

Top Management Commitment

The decision of company management to control energy costs is a vital first step

This must be clearly stated and understood by all within the company. Senior management should participate in energy committee meetings or in other energy related activities The company managing director may have the Energy Manager report directly to him, particularly at the beginning of the energy management programme.

It is often useful for the company to publish a formal statement of its energy policy This can be used to define company activities in energy matters for its employees and it can inform the general public about the company's commitment to energy efficiency

Finally, an important part of top management commitment is to appoint the responsible organisation for implementing the energy management programme This is commonly at two levels, the Energy Manager and the Energy Committee, and these are discussed further below. Evidence of top management commitment will be seen in the level of support given to the Manager and the Committee, especially the resources authorised.

The Energy Committee

Because energy concerns different departments within a firm, an effective energy management programme must involve a number of people. In many companies, a committee is formed to include representatives of important departments While unnecessary bureaucracy must be avoided, there are advantages to having an active Energy Committee:

- it can encourage communications and the sharing of ideas amongst various departments (and even other plants) throughout the company
- it can serve to obtain agreements on energy conservation projects which affect more than one department
- it can provide a stronger voice to top management than a single manager normally could.

The composition of the Energy Committee will vary from one company to another, depending on the existing management structure, the type and quantity of energy used and other company-specific factors.

When should the Committee meet ? This will depend on the importance of energy costs in the overall cost structure of the company and what projects are in progress at any time. normally a monthly meeting is usual, so that monthly production and energy consumptions may be reviewed regularly by the Committee This review would include a comparison of actual performance against previously set targets and budget figures, as well as against previous months. Other items for the agenda should be a review of the status of energy conservation investments, in progress or planned.

The Energy Manager

Forming an Energy Committee is not enough. Someone is needed to implement the policies and directives of the Committee, and to provide the data needed by the Committee to make decisions. The appointment of an Energy Manager is therefore an essential step in the setting up of an effective energy management programme in most companies. The role of the Energy Manager will vary from company to company but he will normally be concerned with the following tasks

- collecting and analysing energy related data regularly
- monitoring energy purchases
- identifying energy saving opportunities
- developing projects to save energy, including the necessary technical and economic evaluations
- implementing projects
- maintaining employee communications and public relations

In general, he should be involved with all matters concerning energy purchases, distribution and utilisation within the plant or company

The skills and experience of the Energy Manager need careful consideration. Technical competence is usually regarded as the primary qualifications, although this may not be as important as often thought In smaller companies, good technical skills may be helpful because the Energy Manager will probably carry out much of the work himself. In a larger company, where technical skills are more readily available, the Energy Manager may well be someone with experience in accounting or general management.

Most Energy Managers are appointed from within the firm This is primarily done because the position requires a good practical knowledge of all aspects of company operations, both technical and administrative.

The particular skills that are important for an Energy Manager include administration and communication Most Energy Managers need to spend much of their time convincing their colleagues and top management to take a specific line of action. The following qualifications are of course ideal and in practice are rarely seen in one individual. However, a good Energy Manager should have many of the following abilities, some of which he will bring to the job and some of which he can learn:

- familiarity with the plant and its production processes and quality requirements
- ability to collect and analyse data, and to interpret data in a form suitable for review by top management
- knowledge of energy-consuming equipment and factors affecting its efficiency (e g boilers, furnaces, heat exchangers, steam systems, lighting, refrigeration)
- engineering skills, to size and select equipment, supervise installation and ensure correct maintenance
- ability to communicate and interact well with both plant management and with line operators and maintenance workers, providing a bridge to promote implementation of management directives and the company energy efficiency policy

- good judgement to know when to call upon outside help such as consultants or equipment vendors to assist problem solving
- proper perspective of the role played by energy in the company, in relation to other elements such as raw materials, capital and labour
- ability to use initiative to develop solutions to problems, and to relate his plant problems to those encountered by others elsewhere or in different industries and to adapt solutions to his own circumstances

Above all, the Energy Manager needs an open mind to view problems from different perspectives and the skill to convince others that savings are both possible and worthwhile if the right measures are taken.

The role of training

The difficulty of sustaining the interest of staff in energy saving programmes might suggest that what is required is to install sophisticated electronic management systems and control in the belief that if this is done the energy bill will take care of itself Such a view is incorrect for reasons which are not always immediately obvious

Clearly, sophisticated techniques and equipment have a part to play But they do not have the ability to acquire insight or understanding into the intricacies of any particular operation Only people can do that, and only people and frequently only those working on the shop floor or in the office - have the capacity to think how things might be changed or improved

People are capable of rethinking existing situations and suggesting improvements which could alter the total energy requirements But why should staff concern themselves in this way, since the energy bill has no direct impact on them personally ? Moreover, even if they should be so thoughtfully motivated, would they know what steps to take and what avenues are available for them to channel their ideas ?

It is important to realise that the savings made through a permanent change in personal attitudes towards the use of energy lie at the root of long term success in this field Essentially this means a permanent change in the habits of all employees in the work place One of the main functions of training is to bring about such a situation.

Motivating staff by simple exhortation to make changes is not certain or even likely to produce permanent habits. But when an employee sees himself or herself being more efficient as a result of training, motivation and personal esteem are greatly enhanced Careful, proper and well structured training can instill a more conscious approach Every worker can be called upon to make an energy saving decision but it is much easier for him to do this if he has been trained in the recognition of a true energy saving decision

Training personnel can reduce overall energy consumption without in any way reducing the standards of working comfort or efficiency In fact to reduce these is a regressive step Far better for all concerned that a more effective employee is produced as a result of this training - which is after all the goal of any training scheme.

FIGURE 1: SCOPE FOR CUTTING ENERGY COSTS

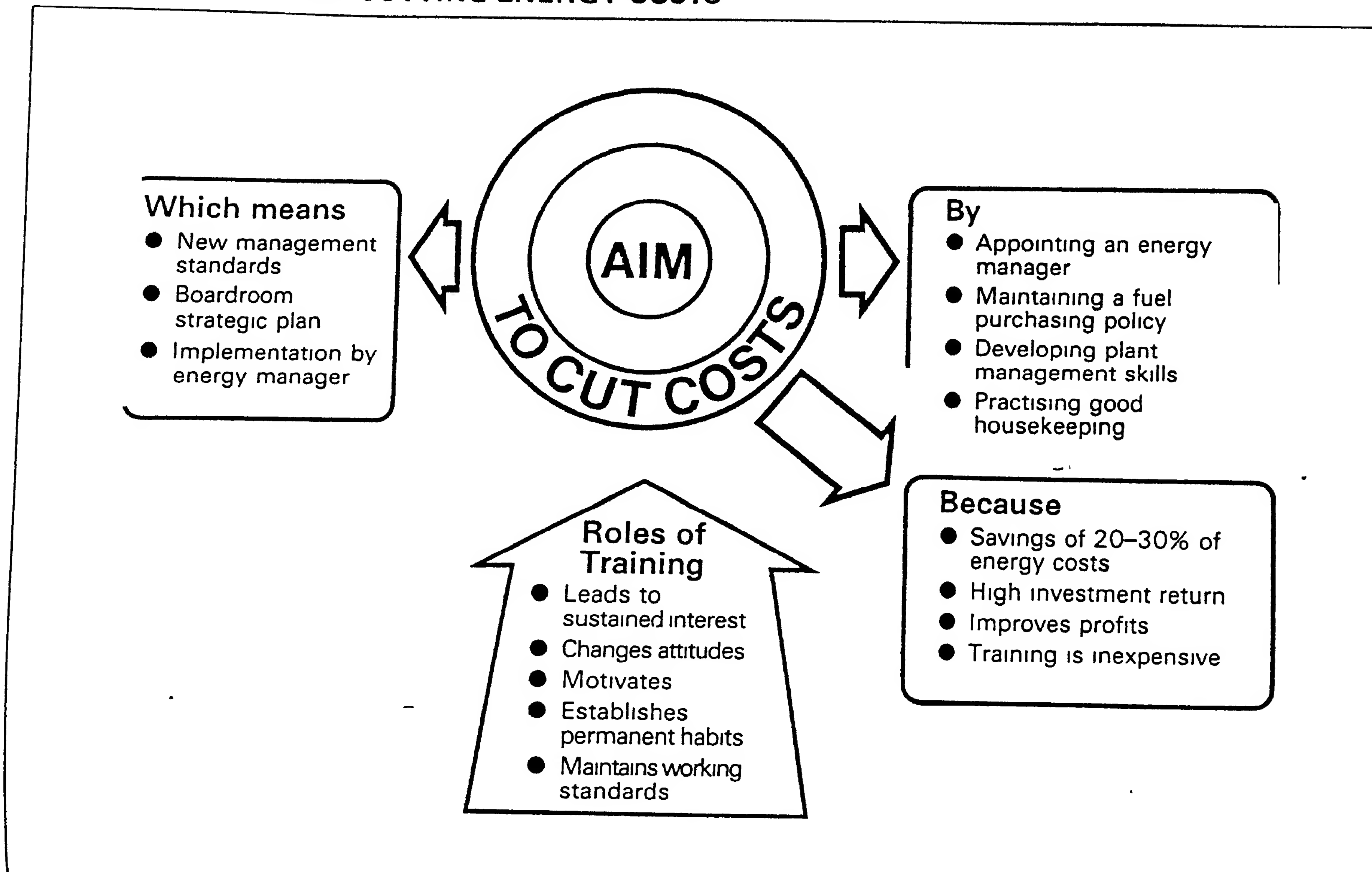


FIGURE 2: ESTABLISHING GOALS AND PRIORITIES

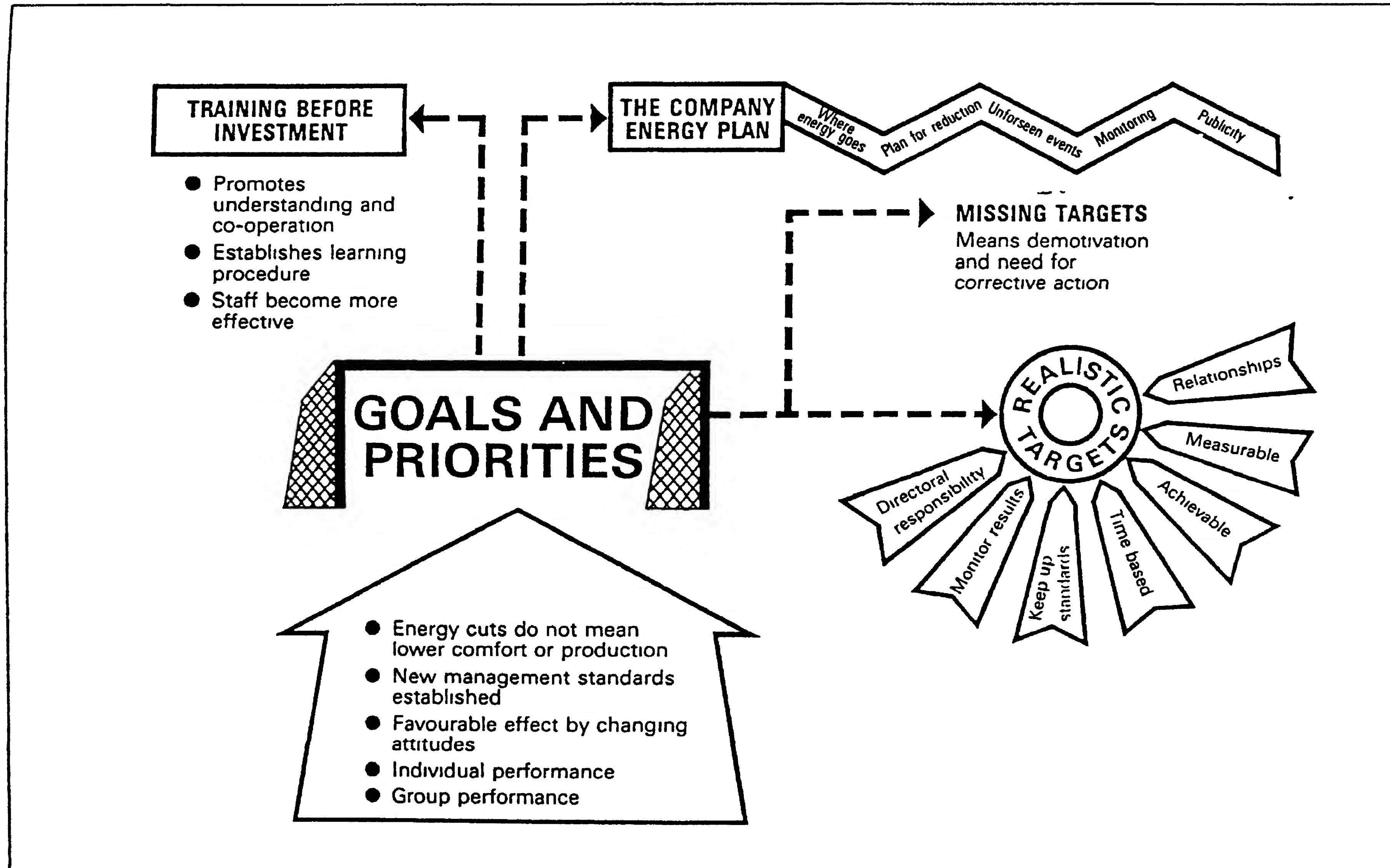


FIGURE 3: THE VALUE OF A STRUCTURED APPROACH

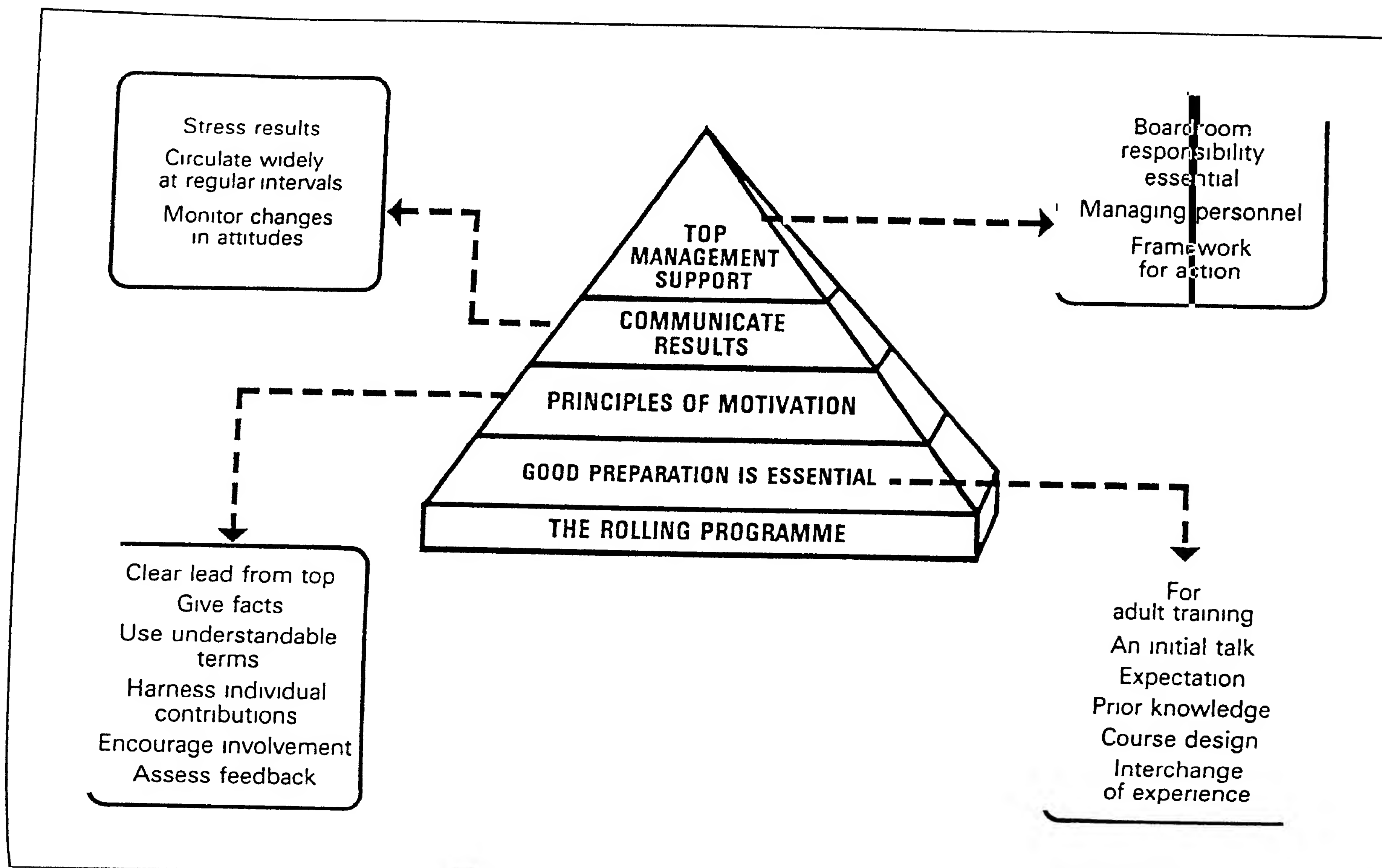


FIGURE 4: ALTERNATIVE APPROACHES TO ENERGY TRAINING

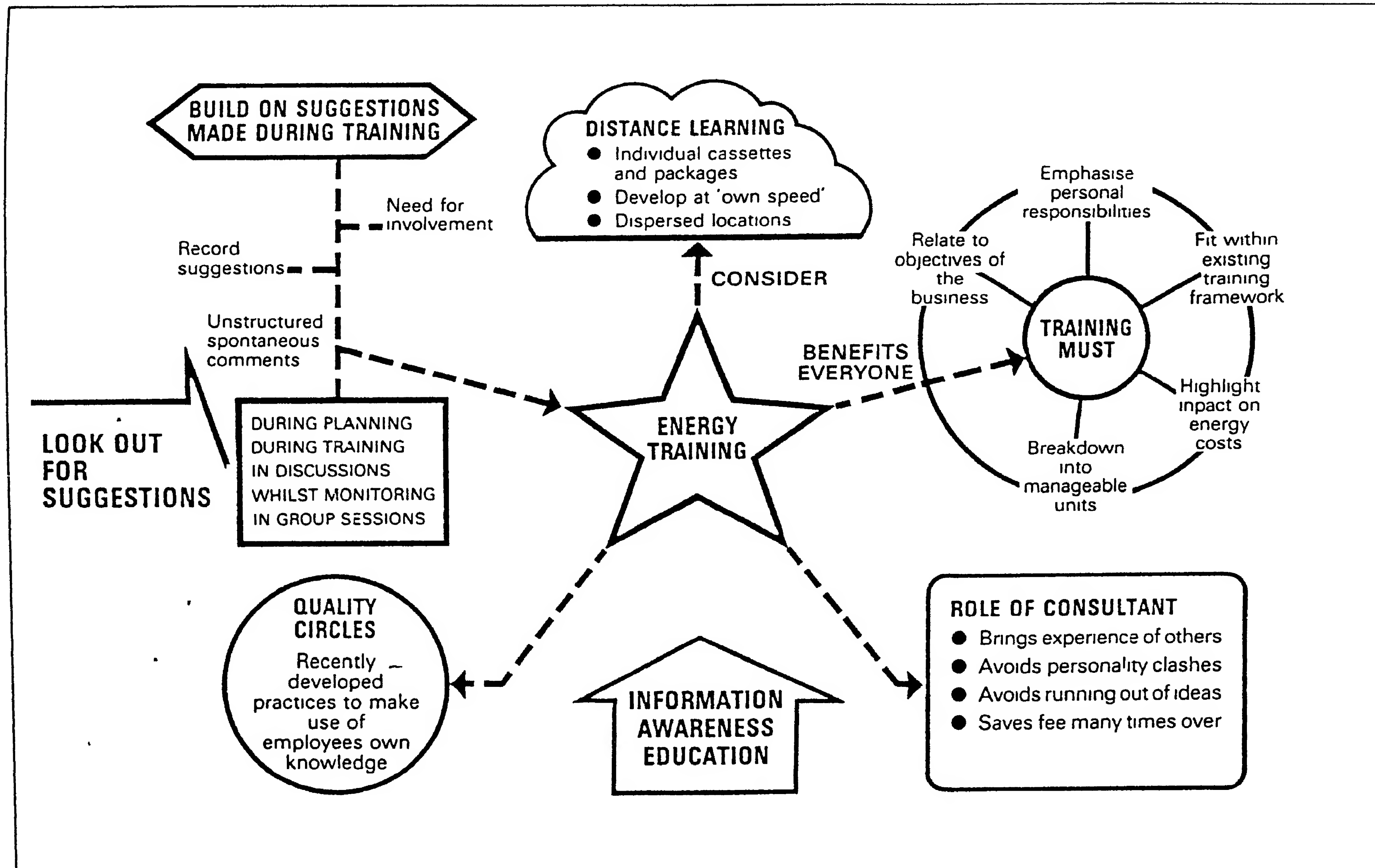


FIGURE 5: TRAINING AIDS AND SEMINARS

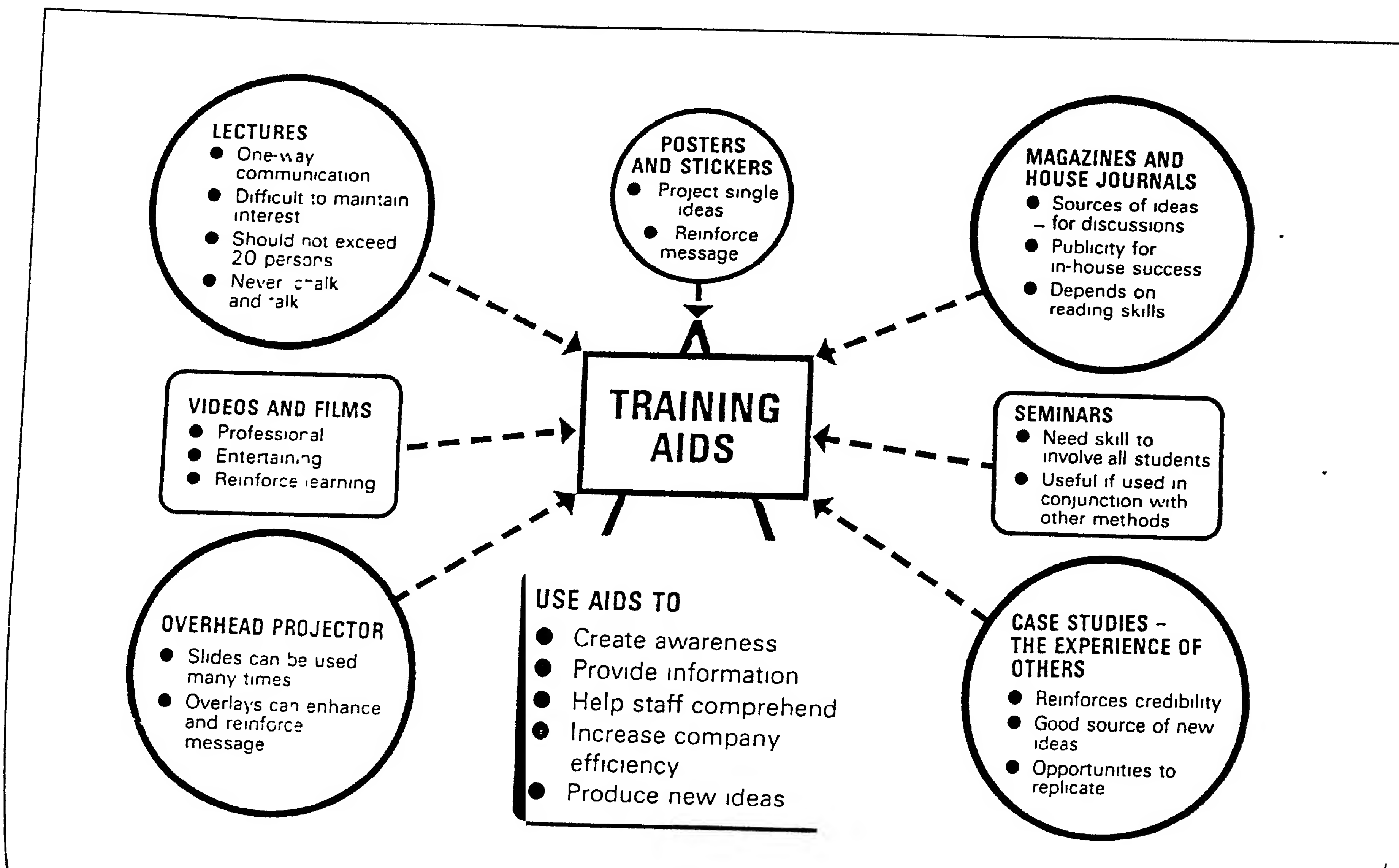


FIGURE 6. SETTING UP THE TRAINING PROGRAMME

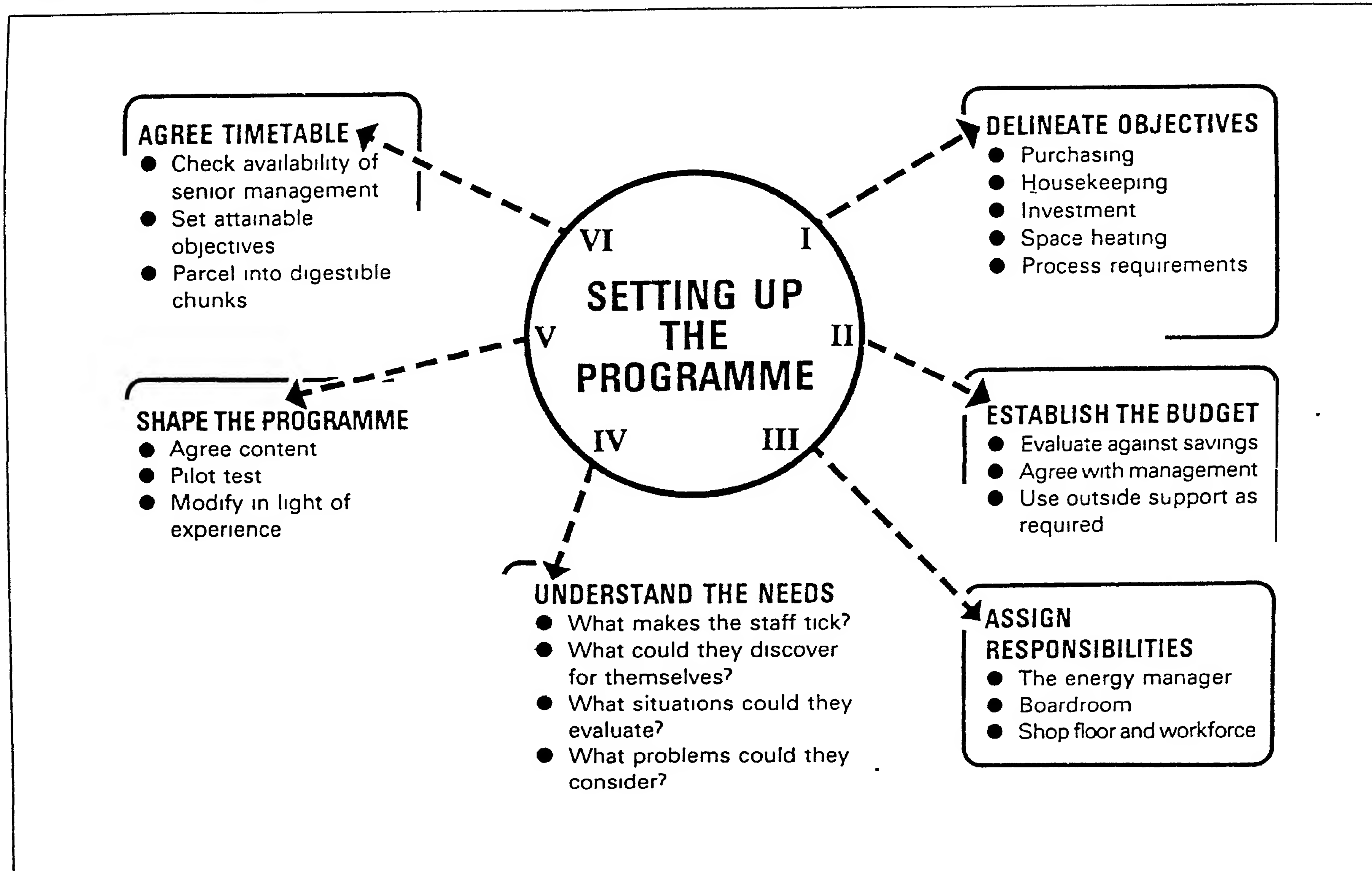


FIGURE 7: AVOIDING MISTAKES AND MAINTAINING MOMENTUM

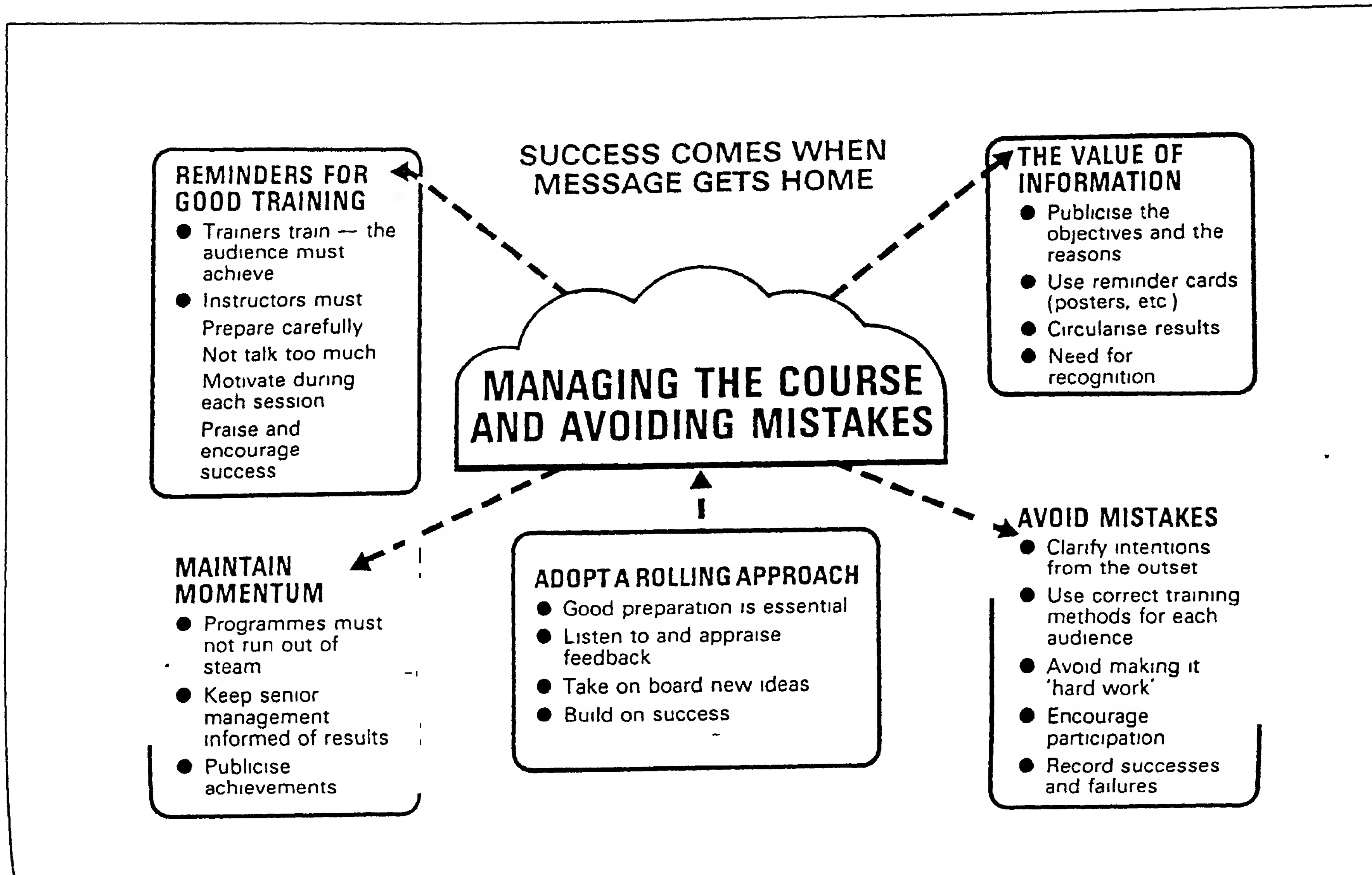
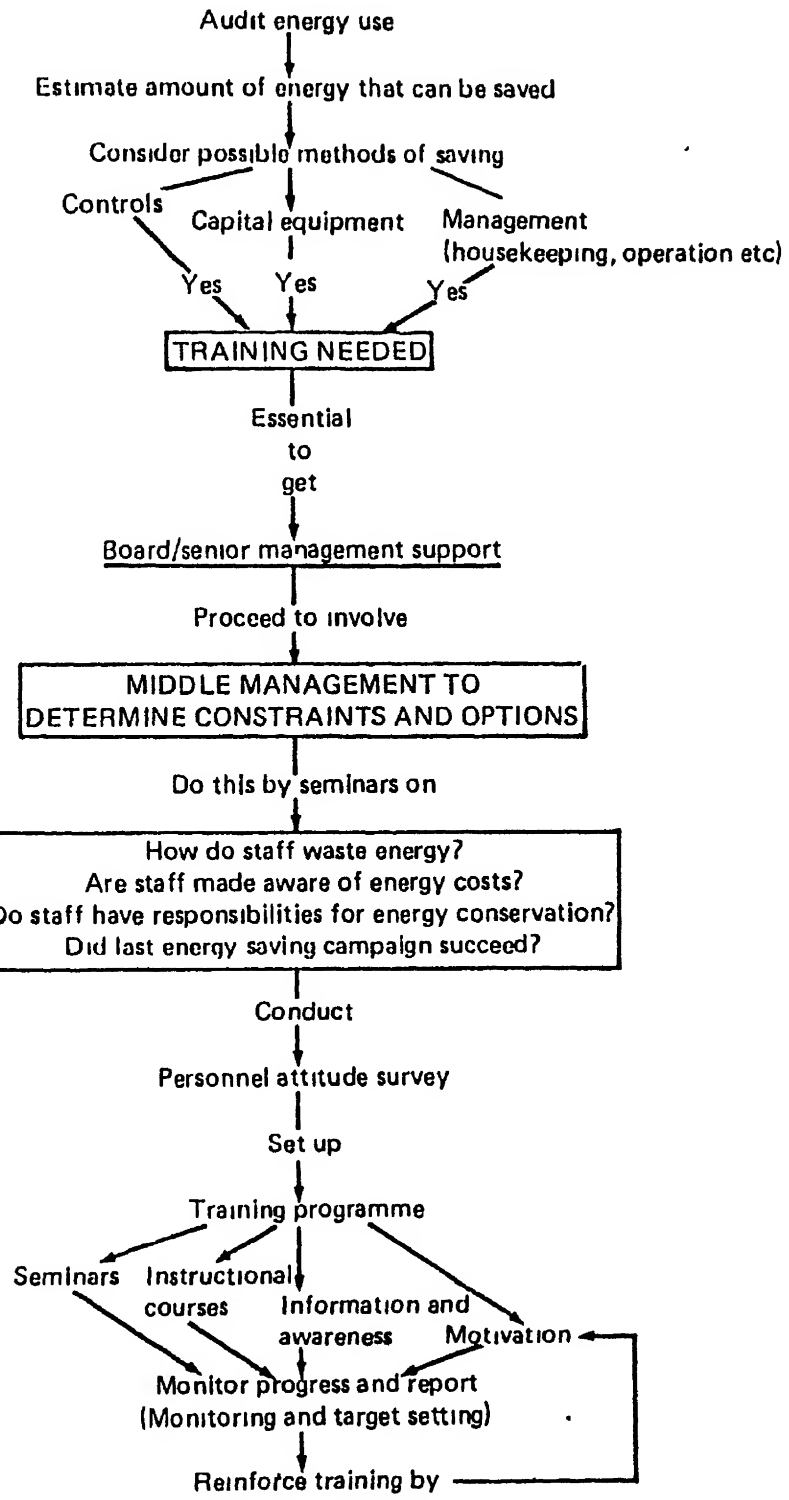


TABLE 8: DEVELOPING AN ENERGY MANAGEMENT TRAINING PROGRAMME



Case study 1. Cogeneration application in pelletizing furnace.

Cogeneration is the sequential production of electricity and heat, steam or useful work from the same fuel source this means that rather than using the energy in the fuel for a single function, as typically occurs, the available energy is cascaded through at least two useful cycles

In the present context, fuel will be used to generate power in a gas turbine and the waste heat available in the exhaust of the turbine will be utilised in the indurating machine The thermal efficiency will be greatly enhanced This is diagramatically represented in Figure 1 Figure 2 shows the present system without cogeneration.

The heat requirement of the pelletization plant in terms of oil consumption is about 150 - 160 K L of furnace oil/day Electricity consumption is about 250,000 kWh to 270,000 kWh per day. This makes it very attractive to have a cogeneration system based on gas turbines because of the high heat to power ration required

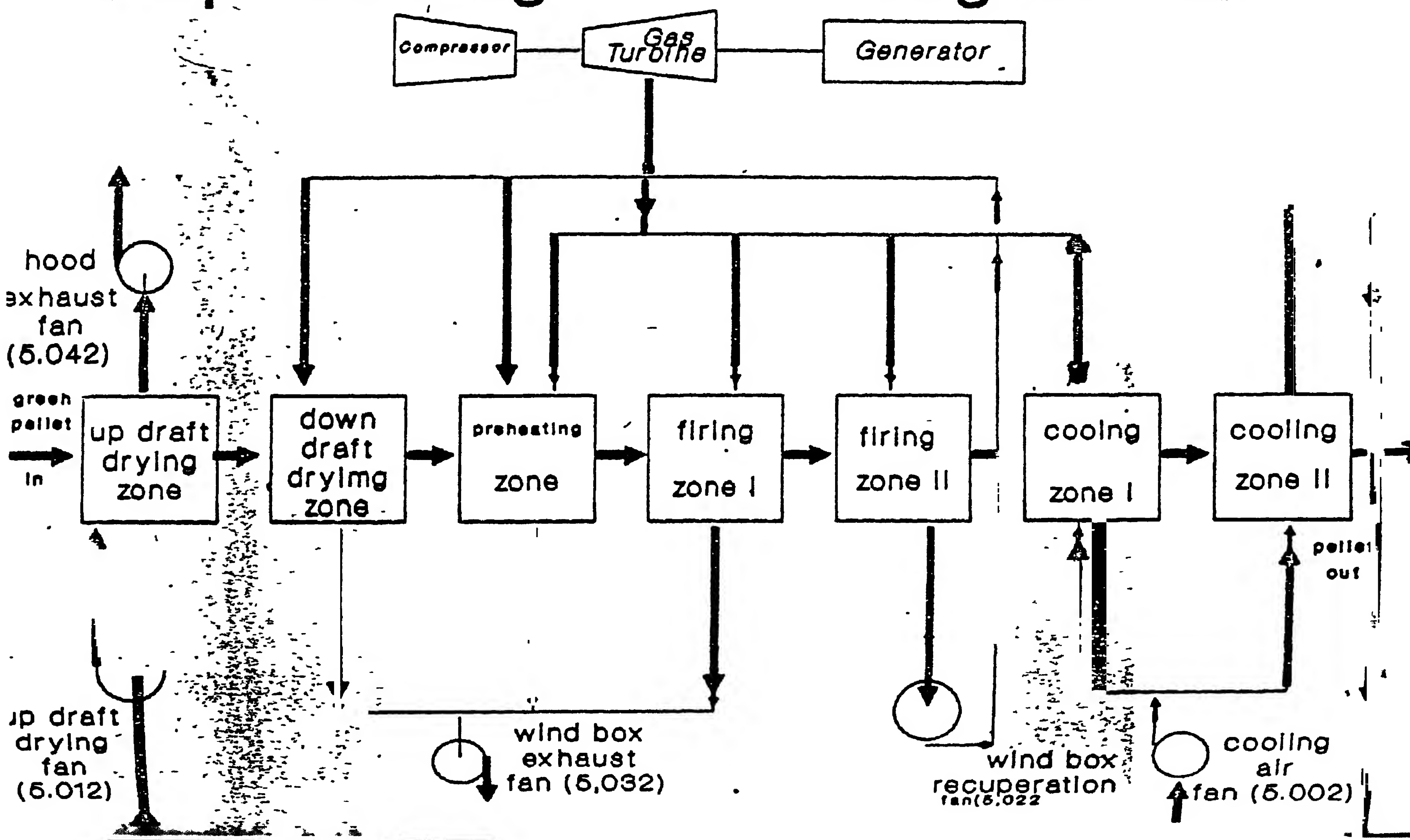
Based on the daily load curve, it was found that the electrical maximum demand was around 10 MW as on 9th Oct 1992 and about 9600 litre/h of fuel oil (maximum consumption) Based on this data and other practical aspects in the plant it is suggested to install two gas turbines of capacities 5 4 MW each, which will meet the normal electrical load of the plant The exhaust gases are to be directed into the pelletizing machine preferably in preheating and firing zone I as shown in Figure 2 The quantity of gases will be about 40 kg/s, amounting to about 144,00 kg/h at 534°C The heat content of these gases will be around 13.8 x 10^6 K.Cal/h, an oil equivalent of 1380 litres/h The introduction of these gases fired into the furnace An economic analysis of the system based at the present purchased power cost (Rs 2 50 kWh) Also this system has to be analysed vis-a-vis the captive power plant that is being set up based on DG sets.

Table 1.1. Comparison of the operating cost of the co-generation system with the present system

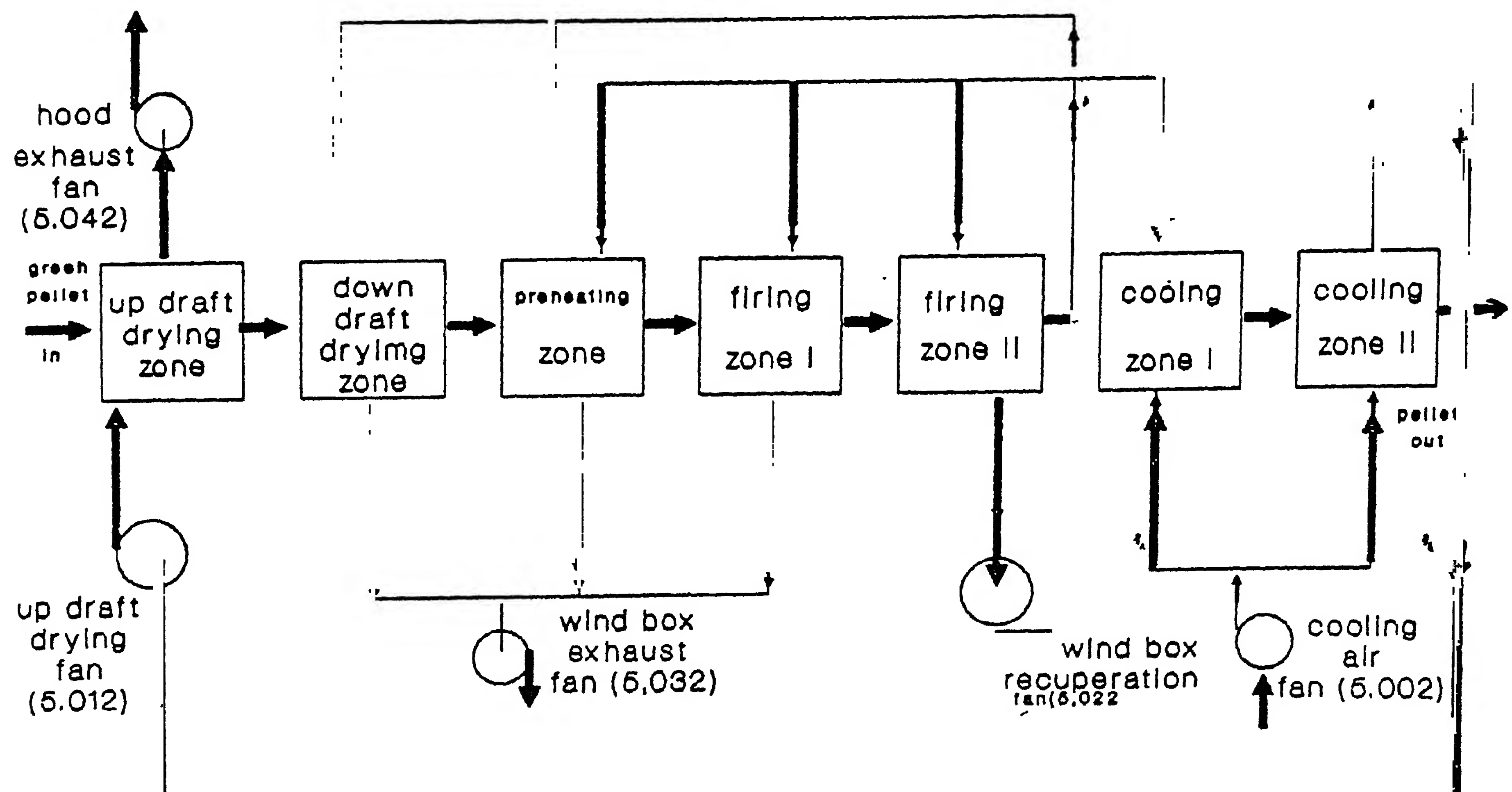
	Hourly consmn	Hourly consmn Cost Rs.
Operation with cogen		
Fuel oil consumed in turbine (ltr)	5520	34,224
Fuel oil consumed in indurating M/c	5520	34,224
Power generated (MW)	10 8	-
Total operating cost		**68,448**
Operating cost without cogen		
Fuel oil consmn in indurating M/c	6900	42,780
Purchased power (MWH)	10 8	27,000
Total operating cost		**69,780**
Net cogen savings (Hourly)		1,332

Note: Cost of purchased power = Rs 2 50 / kWh
Cost of fuel oil = Rs.6 20 / litre

Simplified Diagram With Cogeneration



PRESENT SYSTEM



Case study 2. Atomiser Plant

Brief Plant Description

Fine tungsten carbide mixed with acetone and other ingredients is sprayed into an atomiser where acetone is evaporated and separated from nitrogen in a scrubber The final granulated tungsten carbide is removed from the bottom

The plant has been provided with one 60 KW capacity thermic fluid heater and 56 Ton total capacity Refrigeration unit for its heating and cooling requirement respectively Hot thermic fluid at about 210°C is circulated through gas heater to heat nitrogen gas and through water heaters to maintain constant temperature in the conical mixtures Pumps and blowers are provided for circulation of liquids and gases Measurements taken and the corresponding calculations are listed in Table 2 1 and Table 2 2

OBSERVATIONS AND RECOMMENDATIONS

Insulation of hot and cold surfaces

It was observed that conical mixers, acetone scrubber, plate heat exchanger, cyclone separators and some sections of hot and cold pipe lines were not insulated resulting energy loss to surrounding atmosphere by conduction, convection and radiation Hence, it is recommended to insulate all exposed hot and cold surfaces, so as to bring the surface temperature close to the ambient temperature (say +/- 5°C) This suggestion will result in the savings of Rupees 10,000 per year and it will pay back with in a year

Integrating heating and cooling circuit of Acetone-Nitrogen mixture

The Acetone-Nitrogen gas mixture evolving from atomiser is chilled from 90°C to 18°C in a condenser and plate heater exchanger to remove acetone The resultant Nitrogen gas is reheated from 18°C to 130°C in a gas heater and circulated back into the atomiser to evaporate acetone Then the cycle continues Since the heating and cooling of gases occur simultaneously, it is possible to integrate the heat exchange system so that chilled nitrogen gas can be heated to around 80°C

and acetone nitrogen mixture can be cooled to 45°C by providing a new heat exchanger in the flow circuit thereby reducing the heating and cooling load simultaneously A simple flow diagram illustrating process integration is given in Figure 3

If this recommendation is implemented, it is possible to save energy worth of Rs.30,000/year. Pay back period will be less than 3 years

Replacing thermic fluid heaters with direct explosion proof electric heaters

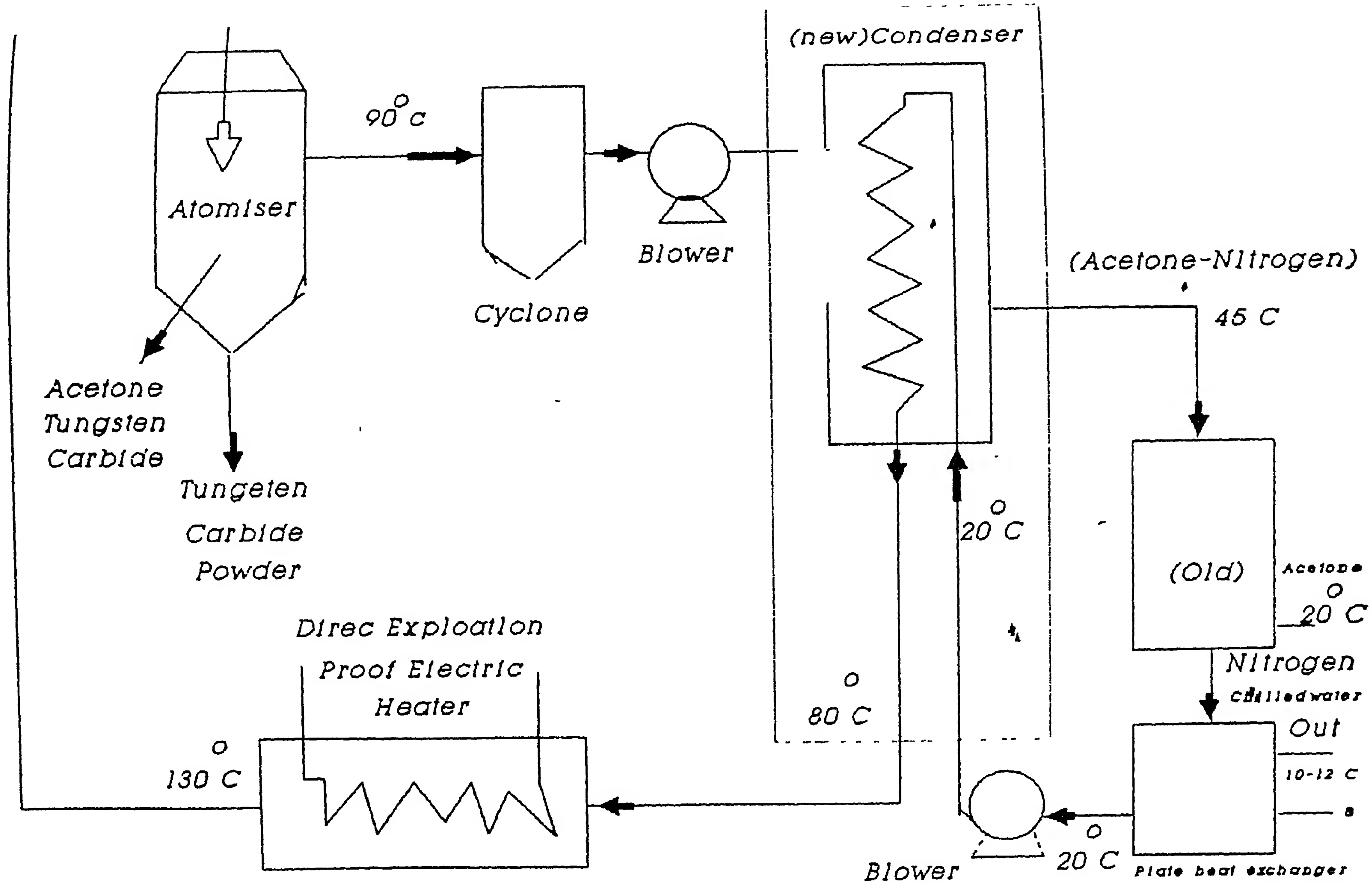
Presently hot thermic fluid around 210°C is circulated by KW pump through gas heater and water heater to heat nitrogen and water Entire heating is done by indirect heating even though electric heaters are used It is suggested to provide explosion proof direct electric heaters like the one installed in Aiswaraya - I, plants, in the gas heater so that thermic fluid circuit can be eliminated This will save thermic fluid pumping cost and radiation losses from the heater surfaces and pipe lines. This will result in a saving of Rs 22,000 per year

By - passing acetone condenser during startup

Entire atomiser and its internal parts have to be heated and maintained around 130°C before starting the spray This process takes about 3-4 hrs to attain the required temperature. During the startup nitrogen gas is passed through both condenser and heater thereby subjected to both heating and cooling This operation not only increases the start up time and also increases the cooling load on the chiller Hence it is suggested to provide by-pass line between condenser and gas heater so the condenser can be by-passed during startup Since atomiser is operated intermittently this suggestion will result in a saving of Rs 20,000 per annum the pay back will be less than a year

Avoiding chilled water flow to atomiser during non-operational hours

It was observed that chilled water is circulated to condensers and plate heat exchangers even in non-operational hours As this will increase the chiller cooling load, it is suggested to stop chilled water flow to atomiser during non-working hours



Atomiser
90°C
Cyclone
Blower
(new)Condenser
(Acetone-Nitrogen)
45 C
Acetone
Tungsten
Carbide
Tungeten
Carbide
Powder
20°C
(Old)
Acetone
20°C
Nitrogen
Chilledwater
Out
10-12 C
Direc Exploation
Proof Electric
Heater
80°C
130°C
Blower
20°C
Plate heat exchanger

Table 2.1. Atomiser Plant

Measurements

Avg no. of operating hours per day	-	3 (Startup) + 3
	-	6 hrs
Heater Capacity	-	60 KW
Thermic fluid inlet temp	-	205 - 210°C
Nitrogen-acetone temp. at atomiser outlet	-	80-90°C
Hot water temp.	-	70-80°C
Nitrogen-acetone temp after condenser	-	22°C
Nitrogen temp after plate heat exchanger	-	20°C
Amount of acetone evaporated per hr	-	250 lit/hr
Percentage acetone recovery	-	95%
Chilled water inlet temp.	-	8°C
Chilled water outlet temp	-	12-14°C
Nitrogen mass flow rate	-	550 NM^3/hr
Surface temp. and area of condenser	-	20°C &
Surface temp and conical mixer (4 nos)	-	70°C &
Surface temp and plate heat exchanger	-	18°C &
Surface temp and cyclone separator	-	81°C &
Avg room temp	-	30°C
Power consp by thermic fluid circulation pump	-	3 75 KW

Table 2.2.

Avg. no of operating hrs/day	- 6 hrs
Heat loss from condenser	- 1000 K Cal/h4
Heat loss from conical mixer	- 800 K Cal/hr
Heat loss from cyclone	- 450 K Cal/hr
Therefore Total loss	- 2 25 K Cal/h4
	- 2 25 x 6 x 300 x 2 50
	- Rs 10,000/year
No of hrs of operation (excluding start ups)	- 3 hrs
N_2 inlet temp to condenser	- 90°C
N_2 Outlet temp from condenser	- 20°C
N_2 outlet temp from gas heater	- 130°C
Nitrogen flow rate	- 687 Kgs/hr
Nitrogen C_p	- 0 25 K Cal/Kg°
Cooling load/hr	- 687 x 0 27 x (90-45)/3040 x 0 8 = 2 0 kWh
Heating load/hr	- 687 x 0 25 x (80-20)/860 = 12 0 kWh
	- (14 0) x 3 x 300 x 2.50 = 31,500
In terms of Rupees	- Rs 30,000/year
No of hrs of operation/day	- 6 hrs
Pump power consumption	- 3 75 kWh/hr
Radiation losses (2% of 60 KW) in fluid circuit	- 3 75 kWh/hr
Energy saved/year	- (5) x 6 x 300 x 2 50 = Rs 22,500
Energy savings	- Rs 22,000/year
N_2 inlet temp	- 90°C
N_2 outlet temp	- 20°C
Flow rate	- 687 Kgs/hr (Density 1 25 Kg/m^3)
C_p	- 0 25 K Cal/Kg°C
No of hrs for startups	- 3 hrs/day (2 hr is sufficient out of 3 hrs)
Heat load	- M CP dt
Extra cooling load/day	- 687 x 0 25 x (90-20)/3040 x 0 80 = 4.0 KW
Total heat loss	- (26) x 300 x 2.50/kWh = Rs 19,500
Heat loss	- Rs 20,000/year

Case study 3. Hard Metal Plant

Aiswarya Reduction Furnace

The tungsten oxide is reduced to get tungsten which is required for the production of tungsten carbide Hydrogen is passed over the trays filled with WO_3 at a specified flow rate It has six (one idle) zones maintained at different temperatures The production capacity furnace which has been modified from the previous old furnace Measurements taken on this furnace are given in Table 3 1 Based on the measurements and calculations the following observations are made

1 The thermal efficiency of the furnace was found to be 6% for the particular grade being manufactured. The % breakup of energy losses is indicated in the Table 3 2

2 The radiation losses of the furnace was calculated to be 37% which is very high This can be brought down to 6 0 % by providing extra insulation so that the surface temperature will be around 50°C This amounts to a savings of around 2 Lakh kWh of electricity per year amounting to Rs 5 0 Lakhs This suggestion will pay back within a year

3 The hydrogen supplied to the furnace for reducing tungsten trioxide carrys away about 31% of the total energy input which is lost to the cooling water This substantial quantity of heat can be recovered to preheat the hydrogen being fed to the furnace to around 300°C using a heat exchanger This will save about 1,42 lakh kWh of electricity amounting to Rupees 3 55 lakhs per year This will pay back within an year

4 The energy consumption during hydrogen regeneration in the molecular sieves, are given in Table 3 3 The present energy consumption for heating and cooling comes to 139 KW per cycle It is suggested to integrate the regeneration cycle by means of a heat exchanger This will save about 18 kWh per regeneration Pay back calculations have to be done after taking into account the investment

Table 3.1.

Aiswarya Furnace

Data

Hydrogen flow rate	- 240 NM^3/hr (60 NM^3/hr x 4)
Hydrogen inlet temperature	- 25°C
Hydrogen outlet temperature	- 350°C
Hydrogen specific heat	- 3 5 K Cal/Kg°C
Hydrogen density	- 0 09 Kg/m^3 at STP
Furnace temp (zonewise)	- 516, 650, 683, 724, 786, 809
Power input to furnace	- 2252 kWh/hr
Wt of material processed	- 7 2 Kgs/hr
Wt of each tray	- 4 38
Total no of trays per hr	- 12 trays
Material processed	- WO_3
Average surface temp of furnace	- 118, 100, 90, 86, 105, 93, 84, 109 = 95°C
Mol wt of WO_3	- 232
Sp heat of WO_3 at 50°C	- o 0832 K Cal/Kg°C
Heat of formation of WO_3	- - 201 45 K Cal/gm mol
Heat of formation of water	- - 57 102 K Cal/gm mol
Specific heat of tungsten	- 0.031 K Cal/Kg°C
Outlet material temp.	- 30°C
Surface area of furnace (Bottom & sides neglected)	- 7 5 x 2 5 x 4 18 = 81 0 m^2

Table 3.2. Aiswarya Energy Balance

Basis - 1 Hr Operation

Heat Input	Material	Energy	Percentage
WO_3	7 2 Kgs	-	-
Tray	12 Nos	-	-
Power Input	93 83 kWh	80,649 K Cal	100 %
Hydrogen	21 6 Kgs	-	-
Total		**80,694**	**100 %**
W	6 02	-	-
Tray	12 Nos.	-	-
Hydrogen	21 42	24733	31 0 %
Heat of reaction	-	4437	5.5 %
Sensible heat to heat Wo_3	-	47810	0 5 %
Radiation losses	-	30000	37 0 %
Cooling zone & unaccountable losses	-	21046	26 0 %
Total		**80694**	**100 %**

Thermal efficiency = 4437 + 478 / 80,694 = 6 0 %

Table 3.3. Hydrogen Regeneration System

Data

Hydrogen flow rate	-	650 NM^3/hr
	-	58 8 Kg/hr
Hydrogen inlet temp to chiller	-	40°C
Hydrogen outlet temp from chiller	-	16°C
Hydrogen temp from blower outlet	-	20°C
Hydrogen temp from heater	-	160°C
Heating cycle time	-	4 hrs
Cooling cycle time	-	4 hrs
No of regeneration	-	One per day

Present Energy Requirement

Power required for heating	-	58 5 x 3 5 x(160-20)x 4/860
	-	119.0 KW/cycle
Power required for cooling	-	58 5 x 3 5 x(40-16)x 0 9/3040 x 4
	-	5 8 kW/cycle

Power Requirement After Heat Recovery

Power requirement for heating	-	58 5 x 3 5 x (160-35) x 4/860
	-	119 0 KW/ cycle
Power required for cooling	-	58 5 x 3 5 x(25-16)x 0.9 x 4/3040
	-	2 18 KW
Savings in KW per cycle	-	133 3 + 5.8 - 119 - 2 18
	-	17 9 KW/ cycle
Therefore Savings per year	-	17.9 x 300
	-	5376 kWh
	-	Rs 13,350

A Review of Electricity Pricing in Developing Countries

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Tata Energy Research Institute
New Delhi

Training Programme
on Energy Planning
for South Asian Countries

Jaipur
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COMPARISON OF ENERGY PRICES FOR DIFFERENT END-USE SECTORS IN BANGLADESH

*Bhaskar Natarajan and Bhavna Bhatia**

Introduction

The energy sector in developing countries in the last two decades is characterized by (a) a shift from biomass-based fuels to commercial fuels, (b) a rapid growth of demand ranging from 12 to 13 percent, (c) energy prices for end-use sectors being subsidized to a substantial extent, (d) financial losses resulting from the two previous trends, and (e) capital constraints leading to problems in shortages in adding to capacity. Another important factor of note is that the energy sector is fully under the control of the government in almost all developing countries.

Energy consumption in the developed countries, on the other hand, either has not increased or has been reduced marginally during this period without any adverse impact on economic growth. For example, per-capita energy consumption in North and Central America was reduced from 240 gigajoules (GJ) in 1973 to 208 GJ in 1989; comparative figures for Europe are 120 GJ (1973), 134 GJ (1979), and 129 GJ (1989).[1] The subsidy for energy was gener-

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Bhavna Bhatian holds an advanced degree in business economics from Delhi University and has been involved in research projects dealing with power planning and policy supported by state electric utilities, the World Bank, Asian Development Bank, and the European Commission.

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ally limited to the essential sectors or a small group of consumers, and there is a trend towards increased investment in demand-side management with a view to increasing capacity utilization.

The crucial role of an efficient energy pricing mechanism has been adequately brought out by DeAnne Julius and Mohan Munasinghe, among others.[2] More important in this discussion on pricing is the need for introducing an integrated approach to investment and pricing decisions. The basic objectives that energy pricing aims to achieve are (a) economic efficiency, (b) social equity, and (c) financial viability. Setting the right prices provides the necessary messages to the supply side for adding to capacity. Price plays a major role in determining the level and pattern of energy demand as well as directing investments towards appropriate energy resources and/or technologies This is particularly so in developing countries, where energy prices are "administered prices," fixed by various departments or committees over time, with little or no relation to either financial viability or economic loss.[4]

Energy pricing policies in most developing countries are drawn out on an ad hoc basis or, at best, on regional or sub-sectoral bases[5] In the 1950s and 1960s, the cost of energy was low, the partial approach posed no major problems, and the losses arising out of this situation were acceptable. With the increase in the cost of energy and the noneconomic factors playing an increasing role in setting prices, the need for a formal integrated approach to energy planning—of which pricing is a major component—never has been more strongly felt.

DeAnne Julius has pointed out that, except for electricity, literature on pricing of individual fuels is slight, with almost nothing written on the economic issues in the setting of coal and natural gas prices.[6] Another report of the Asian Development Bank points out that decisions on energy prices have been in most cases been influenced by political and social considerations, and not as much by economic considerations[7] Setting energy prices below full cost was a widely prevalent practice, particularly prior to the two oil price shocks of 1973-1974 and 1979-1980. Developing countries responded differently. While India did not pass on the full increase in international prices to consumers, Bangladesh and Pakistan delayed passing on the increase. P. M. Meier points out that price setting is actually a complex mix of taxes, subsidies, and accounting costs.[8]

It is in this context that this paper attempts a comparison of prices of alternative sources of commercial energy in Bangladesh for major end uses with a view to the direction in which the economy should move with respect to alternate energy sources of commercial energy for different end uses. An overview of demand and supply trends for commercial energy in Bangladesh will be followed by a discussion of the prevailing pricing policies in the various energy subsectors.

Supply of Commercial Energy Sources

As in most developing countries, traditional energy has an overriding importance in meeting the energy needs in Bangladesh. Though the consumption of commercial energy forms has been growing rapidly and the share of the traditional forms of energy has been falling, noncommercial energy fuels (firewood, cow dung cakes, biomass, and animate forms of energy) still account for approximately 65 percent of the total energy requirements in Bangladesh.

Natural gas is the main source of commercial energy in Bangladesh. In the early 1990s, the country has 310 billion cubic meters of proven natural gas reserves, almost all of which are located in the eastern side of the Padma-Jamuna river complex (east zone). The production of natural gas increased from 0.44 million cubic meters (mcm) at the time of independence in 1971 to 0.69 mcm in 1974, a growth of 13.2 percent. Natural gas production fell sharply by 33.7 percent in 1975, but soon picked up and increased to 3.5 mcm in 1987, with a growth rate of 10.9 percent per annum.

Bangladesh has some potential coal and peat resources as well. The coal deposits in the Jamalganj area were discovered in 1959, with coal seams 0.69 to 32.3 meters thick at depths of 823 to 1,057 meters, the estimated reserves were put at 1 billion tons. However due to their depth, development of these coal fields is presently reported to be uneconomic.[9] All coal consumed in the country is presently imported.

In spite of a very large river system, hydropower potential of Bangladesh is rather modest because of flat terrain. Natural gas and furnace oil are primarily used for power generation. The nation's power system is characterized by gas plants in the east zone, while the plants in the west zone use expensive imported fuel oil. Also, there are a large number of small stations scattered in the country, ranging in size from 50 to 1,200 kilowatts. These are mostly steam diesel and gas turbines. Despite their low efficiencies, these have to be kept in service due to the shortage of generation capacity.

Total installed electricity capacity in Bangladesh has grown from 667 megawatts (MW) in 1974/75 to 1,976 MW in 1987/88, of which 230 MW is hydroelectric and 1,746 MW is thermal capacity (table 1). The share of hydropower in total electricity generated has declined from 26.8 percent in 1975 to 9 percent in 1987, whereas the share of electricity from natural gas has increased from 40.6 percent in 1975 to 56 percent in 1987 (table 2).

Commercial Energy Consumption in Bangladesh

Final commercial energy consumption in Bangladesh rose from 1.39 million tons oil equivalent (mtoe) in 1975 to 2.2 mtoe in 1985 and 3.57 mtoe in 1987,

Table 1
TRENDS IN INSTALLED CAPACITY OF UTILITIES IN BANGLADESH, 1974/75-1987/88
(in megawatts)

Year	Hydro	Gas	Diesel	Coal	Total
1974/75	80	371	85	131	667
1975/76	80	426	132	131	769
1976/77	80	426	130	131	767
1977/78	80	426	128	118	752
1978/79	80	426	128	84	718
1979/80	80	426	235	81	822
1980/81	80	426	226	81	813
1984/85	130	564	251	195	1,140
1985/86	130	633	238	170	1,171
1986/87	130	1,069	238	170	1,607
1987/88	230	1,468	278	170	1,976

Source: Bangladesh Power Development Board, *Annual Reports*

Table 2
TRENDS IN ELECTRICITY GENERATION IN BANGLADESH, 1975-1987
(in million kilowatt-hours)

Year	Oil	Gas	Hydro	Total
1975	531.0	660.0	436.0	1,627
% of total	32.6	40.6	26.8	100
1977	597.0	900.0	437.0	1,934
% of total	30.9	46.5	22.6	100
1979	719.0	1,096.0	587.0	2,402
% of total	30.0	45.6	24.4	100
1980	626.0	1,144.0	583.0	2,353
% of total	26.6	48.6	24.8	100
1982	745.0	1,758.0	533.0	3,036
% of total	24.5	58.0	17.5	100
1983	632.0	2,139.0	662.0	3,433
% of total	18.4	62.3	19.3	100
1984	734.0	2,335.0	897.0	3,966
% of total	18.5	58.9	22.6	100
1985	822.0	3,309.0	739.0	4,870
% of total	16.9	67.0	15.2	100
1986	1,313.0	3,362.0	450.0	5,125
% of total	25.6	65.6	8.8	100
1987	2,065.0	3,300.0	530.0	5,895
% of total	35.0	56.0	9.0	100

Source: Bangladesh Power Development Board, *Annual Reports*.

registering an annual growth rate 8.1 percent. The per-capita consumption of commercial energy has increased from 28 kilograms of oil equivalent (kgoe) in 1975 to 50 kgoe in 1987. During the 1970s, oil was the prime source of energy The share of oil in the total commercial energy consumption was as high as 66 percent in 1975, but declined to 50 percent in 1982 and to 34 percent in 1987. Until 1984, all oil consumed in the country was imported. The import of hydrocarbons, in absolute terms, has been overall on the rise, 1.39 mtoe in 1974/75, reduced marginally to 0.84 mtoe in 1980/81, and resuming the rise to 1.77 mtoe in 1986/87. However, the rate of net imports of oil and petroleum products to total primary commercial energy available in the country declined from 64 percent in 1974/75 to 60 percent in 1980/81 and further to 37 percent in 1987. The net oil dependence has fallen by 19.8 percent during the period 1974 to 1985. Of the total oil consumption decline of 19.8 percent, that of oil and petroleum products by domestic and commercial sectors accounted for 10.5 percent Decreased dependence on oil and petroleum products by the transport and industries sectors accounted for 5.2 percent and 4.2 percent, respectively, of the total decline.

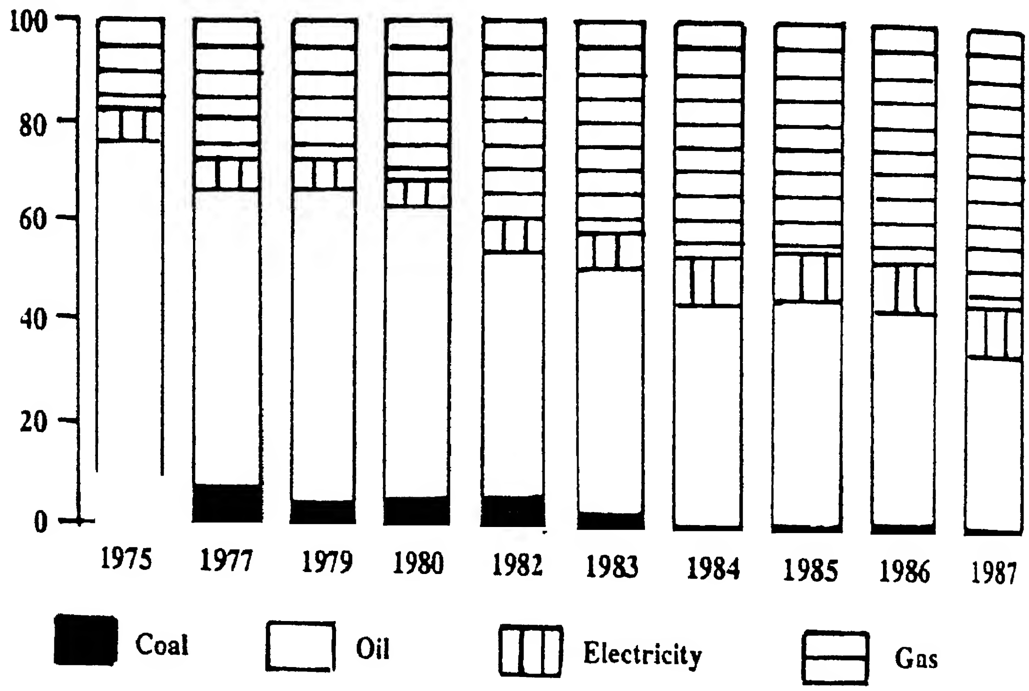
Reduced dependence on oil has been accompanied by a rising share of natural gas in total commercial energy consumption, from 17.6 percent in 1975 to 39 percent in 1982 and more than half (54.5 percent) of the demand for final energy in 1987. Thus, the relative position of oil and gas reversed between 1975 and 1987.

The consumption of coal has been erratic due to supply constraints. Its share in final energy consumption declined from 8 to 9 percent during mid-1970s to 5 to 6 percent in early 1980s. In the mid-1980s, the share of coal in total final energy consumption was around 1 to 2.5 percent. The share of electricity in final energy consumption remained almost stable during the period 1975 to 1982 at 7 percent. Since then, the share has gradually increased to 10.6 percent in 1987. Figure 1 indicates sources of commercial energy in final consumption during the period 1975 to 1987.

In terms of the sectoral distribution of final consumption of various sources of commercial energy, the industrial sector is the primary consumer, accounting for more than 50 percent of the total energy consumed in the country in 1987. In 1975 nearly 40 percent of the commercial energy requirements were met by oil. Natural gas accounted for 33 percent of final energy consumption by the industrial sector. By 1980 the share of gas had risen to more than 50 percent and that of oil declined to 30 percent. As a result of the government's policy to reduce dependence on imported oil and intensified efforts to develop natural gas as a commercial energy source, the proportion of oil consumed by the industrial sector declined to 6 percent in 1986 and the share of natural gas rose to 78 percent. Almost all the coal available in the country is consumed by the industrial sector. However, the share of coal in total energy consumed by

Figure 1

SHARE OF VARIOUS SOURCES OF COMMERCIAL ENERGY
IN FINAL ENERGY CONSUMPTION, 1975-1987
(in percent)



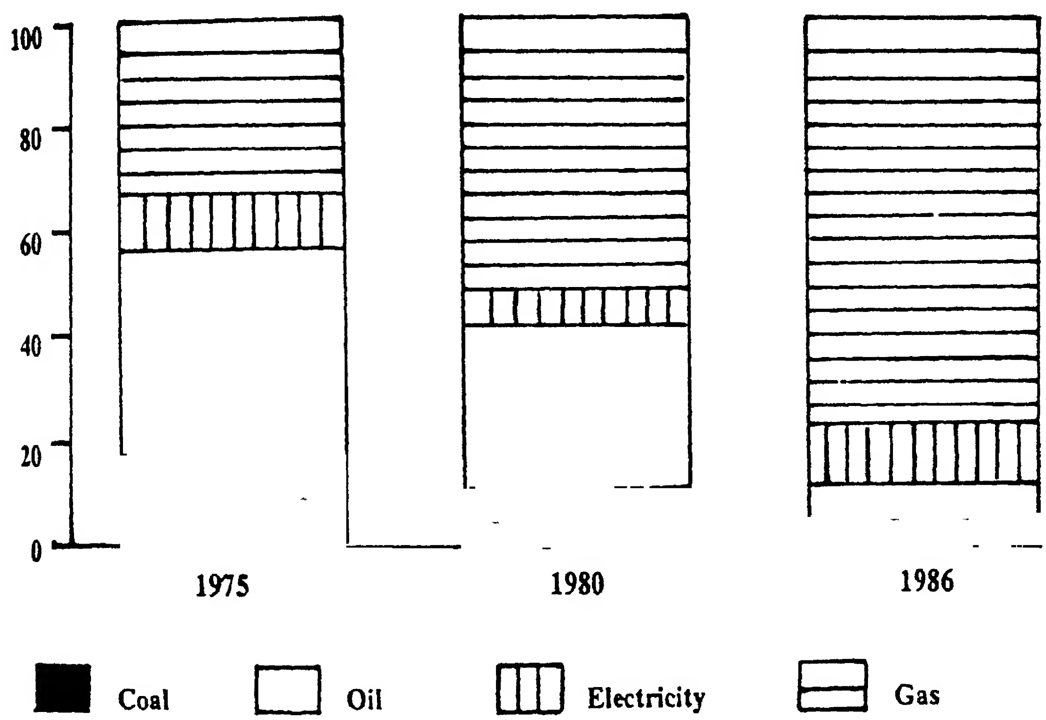
industry fell from 18 percent in 1975 to 11 percent in 1986 The share of electricity varied between 6 and 11 percent during this period (figure 2).

The domestic sector has the second highest share of commercial energy consumption despite its gradual decline from 26 percent in 1975 to 23 percent in 1980 and still further to 20 percent in 1986. Within the domestic sector, between 1975 and 1986, oil consumption fell significantly in relative terms and has been overtaken by gas and electricity. The relative share of electricity in total energy consumed has increased by a factor of 3.5, from 3 7 percent in 1975 to 13 percent in 1986 (figure 3).

The share of commercial energy consumed by the transport sector has remained more or less stable—around 17 percent during the period 1975-1986. Almost the entire energy demand in this sector is met by oil and petroleum products (figure 3). The share of commercial energy consumed by the agricultural sector has increased from 4 percent in 1975 to 7 percent in 1986. This increase has been brought about by a significant rise in the consumption of oil as the primary source (diesel is used for irrigation pumpsets). Oil consumption in the agricultural sector has grown at an annual rate of 12.8 percent during this span. Though the commercial sector accounts for a very low proportion of the total final energy consumed (2 percent), this sector recorded the fastest growth

Figure 2

INDUSTRY'S SHARE OF VARIOUS SOURCES OF ENERGY IN FINAL ENERGY CONSUMPTION, 1975, 1980, 1986
(in percent)



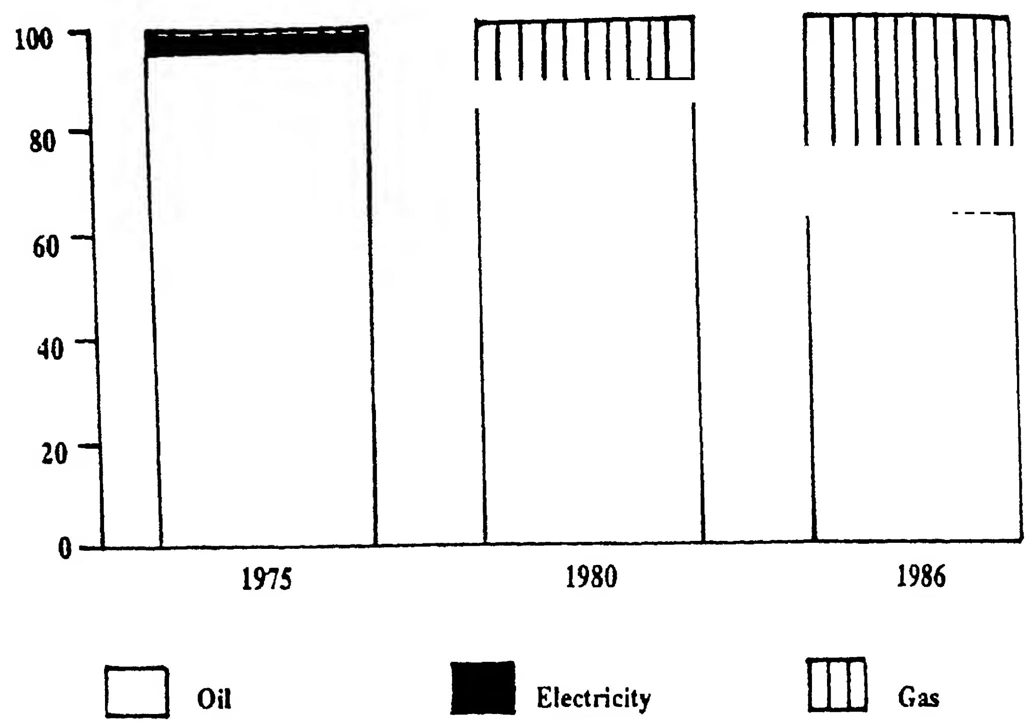
rate of 28 percent during this period. Natural gas is the prime source of energy consumed by the commercial sector, accounting for 86 percent of the total sectoral energy consumption in 1986.

Energy Prices in Bangladesh

The energy sector in Bangladesh is the responsibility of three government-owned organizations that regulate the production, distribution, and import of energy products. The Bangladesh Petroleum Corporation (BPC) dominates the petroleum sector. Established in 1977, it is charged with the responsibility of importing, exporting, refining, and marketing crude oil and petroleum products. The structure of BPC includes one set of companies for petroleum processing and another for marketing these products. The petroleum-processing companies are Eastern Refineries Ltd. (ERL), two lubricating-oil blending companies, an asphalt bitumen plant, and a liquefied petroleum gas (LPG) bottling plant. The distribution and marketing of petroleum products is the responsibility of

Figure 3

DOMESTIC-SECTOR SHARE OF VARIOUS SOURCES OF ENERGY
IN FINAL ENERGY CONSUMPTION, 1975, 1980, 1986
(in percent)



three marketing companies—Burmah Eastern, Jamuna Oil Company, and Meghna Petroleum Company.

The overall responsibility for setting prices for petroleum products rests with the cabinet. The prices of petroleum products are fixed on a cost-plus basis. The costs cover procurement costs, refinery charges to Eastern Refineries, inland transportation, profit margin to all marketing companies, and charges due to foreign-exchange fluctuations. The retail prices are regulated by local authorities on an ad hoc basis. Table 3 shows the trends in prices of various petroleum products for the period 1980-1988. The price of LPG has grown at the fastest rate—9.6 percent annually. The price of kerosine and diesel has grown at 7 percent and 6.4 percent per annum, respectively, during this period. The price rise was the lowest for fuel oil. Between 1972 and 1974, the price of kerosine was held lower than that of diesel, which led to the use of kerosine in transport vehicles. To eliminate this, kerosine and diesel prices have been kept the same since 1974. The price of fuel oil is significantly lower than kerosine to ensure that kerosine is not diverted to industrial use. The price of crude oil (imported) and petroleum products expressed in real terms are given in table 4.

Table 3

PRICES OF PETROLEUM PRODUCTS, 1980-1988[a]
(in taka per imperial gallon)

Year	Premium Gasoline	Kerosine	High-Speed Diesel	Fuel Oil	Liquefied Petroleum Gas
1980	48 66	17 65	22 50	13 00	54.36
1981	52.52	22 50	22 50	16 68	54.31
1982	69.30	32 81	32 81	24.54	54.36
1983	75.36	32 81	32 81	24.54	103 00
1984	76.15	32 82	32 82	24.55	105 00
1986	61.51	30 50	30.50	21.37	113 50
1987	61.51	30 50	30.50	21.37	113 50
1988	61.51	30 50	30.50	21.37	113.50

[a]Prices for 1985 missing from data source.
Source Bangladesh Petroleum Corporation, *Annual Reports*.

During the period 1973 to 1985, real prices of crude oil increased ninefold while that of gasoline and kerosine increased a little more than a factor of 2.5. There was a fall in the real price of diesel in 1974-1975, and thereafter the price has shown an increase but at a slower rate.

The principal company in the natural gas subsector is the Bangladesh Oil Gas and Minerals Corporation (BOGMC), which was formed in 1985 by merging the former Bangladesh Oil and Gas Corporation with the Minerals Corporation. BOGMC is responsible for the exploration and development of oil, gas, and minerals as well as the operation of the gas fields and marketing of gas. Bangladesh Gas Fields and Sylhet Gas Fields are the two gas-producing companies. For transmission, distribution, and marketing of gas, there are three companies: Titan Gas Transmission and Distribution Company, Bakhrabad Gas Systems Ltd., and Jalalbad Gas System.

BOGMC is controlled by the government. Wellhead prices are determined by the financial requirements of the gas field companies while end-use prices have to ensure a sound financial position for the gas distribution company. An indigenous resource, natural gas's price is not affected by fluctuations in the international price or the exchange rate. Trends in natural gas prices to different consumer groups are summarized in table 5. The price of natural gas supplied for power generation is about half of that for industries and about one-third of that for the commercial sector. The policy intention is to encourage the

Table 4

REAL PRICES OF IMPORTED CRUDE AND PETROLEUM PRODUCTS, 1974-1985
(1973 = 100)

Year	Crude Oil	Gasoline	Diesel	Kerosine
1974	304	144	90	115
1975	357	139	97	144
1978	480	177	134	193
1979	453	157	119	171
1980	777	225	155	213
1982	1,113	253	178	373
1984	900	312	226	332
1985	898	258	187	288

Source N J D Lucas et al , *Energy Policies in Asia. A Comparative Study* (Singapore McGraw-Hill Book Company, 1987)

Table 5

END-USE PRICES OF NATURAL GAS, 1974-1989
(in taka per thousand cubic feet)

Year	Power	Fertilizer	Industrial	Commercial	Domestic	Single Burner	Double Burner
1974	3 72	3 72	7 2	12.00	12.00	15 00	28 00
1980	7 75	7.75	18 0	19 00	18.00	22 00	40.00
1981	9.30	9.30	27.75	28 00	20 00	25 00	45 00
1982	10 50	10.50	31.00	31 00	27.00	35 00	65 00
1983	11.50	11.50	36 00	36 00	34.00	45 00	80 00
1984	13 05	13 05	36 00	45 20	34.00	45 00	80 00
1985	15 66	15 66	43 20	54 24	40 80	60 80	100 00
1986	19 09	19 09	52.14	65 39	44 88	66.00	110 00
1987	24 82	24 82	52 14	85 00	56 00	80 00	130 00
1988	28 54	28.54	69 96	97 75	56.10	92.00	150.00
1989	33 00	33.00	70 00	110 00	65 00	100 00	170.00

Source: Bangladesh Oil, Gas and Mineral Resources Corporation, *Annual Reports*

substitution of fuel oil for natural gas in power generation and to keep the price of fertilizers low to encourage its use in the agricultural sector.

The Bangladesh electricity system has developed into two separate parts for the east and west zones. The power systems in the two zones were interconnected in December 1982 by a 230-kilovolt double-circuit transmission line. Electric power generation, transmission, and distribution is the responsibility of the Bangladesh Power Development Board (BPDB). BPDB distributes electricity throughout the country except in some rural areas which are served by the Rural Electrification Board (REB). Created in 1977, the REB distributes power in rural areas through a system of cooperatives called Palli Biduyat Samities (PBSs).

Electricity tariffs are laid down by BPDB and are uniform throughout the nation. In addition to BPDB, PBSs set their own tariffs with the approval of the REB. As is the case in most developing countries, the tariffs in BPDB are also uneconomic. The cost of operations have been higher than revenues realized. Table 6 gives details of average revenue and cost per unit of electricity sold. The substantial losses incurred by BPDB have been attributed mainly to the inability to keep tariffs at a level consistent with the costs.

However, in recent years BPDB has made serious efforts to simplify tariffs and relate them to the cost of supply. BPDB's tariffs were raised by 38 percent in September 1978, by 40 percent in October 1980, and by a further 40 percent in July 1982; tariff revisions have been carried out annually since the latter year. Tariffs were raised by 3.2 percent in 1983, 9.5 percent in March 1984, by 3.4 percent in December 1984, and by 16.4 percent in September 1985.

A new, simplified set of tariffs were introduced in August 1987, where BPDB's average tariff was raised by 15 percent bringing it to about 73 percent of the economic cost of supply. The number of tariff categories was reduced from 18 to 10 and the blocks of consumption were also reduced. In addition, new two-part time-of-day tariffs for 33- and 11-kilovolt consumers were also introduced. Time-of-day tariffs were instituted for large industrial consumers as well.

Comparison of Prices of Commercial Energy Sources

The costs, both financial and economic, of alternative sources of commercial energy for major consumer categories are compared in table 7. Natural gas is by far the cheapest commercial fuel source in Bangladesh. The domestic costs of petroleum fuels are far higher than those of natural gas. The costs of gas to the power and fertilizer sectors on a British thermal unit (Btu) equivalent basis amount to only 23 percent of those of heavy fuel oil, while for industries gas prices amount to 49 percent of those of fuel oil. Compared to kerosine as an

Table 6

AVERAGE REVENUE AND AVERAGE COST OF SUPPLY FOR THE BANGLADESH POWER DEVELOPMENT BOARD, 1981/82-1987/88
(in taka per kilowatt-hour)

Year	Average Revenue	Average Cost
1981/82	1.00	1.19
1982/83	1.28	1.10
1983/84	1.29	1.12
1984/85	1.40	1.33
1985/86	1.66	1.80
1986/87	1.73	1.75
1987/88	1.92	2.01

Source Compiled from Bangladesh Power Development Board, *Annual Reports*

Table 7

COMPARISON OF MARKET PRICES OF COMMERCIAL ENERGY, 1988/89[a]
(in taka per million British thermal units)

	Natural Gas	Coal	Diesel Kerosine	Fuel Oil	Electricity
Electric power	30.33 (21.30)			130.20	
Fertilizer	30.33 (21.30)			130.20	
Industry	63.72 (21.30)	93.94		130.20	674.09 (1,181.13)
Commercial	103.88 (21.30)	93.94	197.87		820.63 (1,576.79)
Domestic	59.62 (21.30)		197.87		600.82 (1,327.67)

[a]Figures in parentheses are the economic costs

Source B Natarajan and B Sehgal, *Comparison of Integrated Energy Pricing Policy in India and Bangladesh*, Part 1 *Bangladesh* (New Delhi, India: Tata Energy Research Institute, October 1990)

alternate fuel, gas prices in the commercial sector amount to 52 percent and in the domestic sector to only 30 percent.

An important alternative to industries without access to gas, such as brick manufacturing, is imported coal, which is sufficiently less costly than fuel oil. The cost of fuel oil to the industries on a Btu-equivalent basis is almost 1.4 times higher than that of imported coal. However, imports of coal are subject to restrictions and therefore reevaluation of this policy may be required to encourage the use of coal as a replacement for the higher cost of imported fuel oil for the industrial sector. Electricity is the costliest source of commercial energy for all the sectors of the economy. The price per million Btu for electricity is 8 to 10 times that of natural gas.

Conclusion

It is well recognized that pricing is an important "soft" option for managing demand in the long run. Price plays an important role in determining the level and the pattern of energy consumption as well as in directing investments towards appropriate energy resources and/or technologies. Energy pricing in Bangladesh, as in most developing countries, is carried out on a partial or sub-sectoral basis. Thus, typically, price of fuel is fixed without seriously considering the impact it may have on the structure of relative prices and hence on the demand for the other fuels. So long as the cost of energy was low, the partial approach posed no major problems and the losses arising out of this were acceptable But with increase in the cost of energy and non-economical factors playing an important role in price setting, the need for a formal integrated approach to energy planning, of which pricing is a component, has never been more strongly felt.

NOTES

[1]*Database of the World Resources Institute, 1992-93* (Washington, D C).

[2]Mohan Munasinghe, *Energy Analysis and Policy* (London: Butterworth, 1990) and DeAnne Julius, *Energy Pricing in Developing Countries: A Review of Literature* (Washington, D C.: The World Bank, Energy Development Paper no 1, October 1981).

[3]Mohan Munasinghe, *Energy Analysis and Policy.*

[4]Asian Development Bank, *Energy Policy Experiences of Asian Countries* (Manila: Asian Development Bank, 1989).

[5]Mohan Munasinghe, *Energy Pricing and Demand Management* (Boulder, Colorado: Westview Press, 1985).

[6]DeAnne Julius, op. cit.

[7]Asian Development Bank, *Energy Policy Experiences of Asian Countries*

[8]P M Meier, *Energy Planning in Developing Countries An Introduction to Analytical Methods* (Boulder, Colorado and London· Westview Press, 1986)

[9]Asian Development Bank, *Electric Utility Databook for Asia and Pacific Region* (Manila Asian Development Bank, 1989)

A review of energy pricing in India

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New Delhi

1. Background

Although the commercial energy sector has been under state control for almost two decades now, energy policy, and particularly energy pricing, have been dealt with in a fragmented manner Under the prevailing regime of administered prices, while the price paid to the producers is based on the average cost approach, that charged to the consumer is generally guided by social and political considerations, often in conflict with other pricing objectives Such a situation would still have been defensible if the benefits of the resultant subsidies had reached the targeted population. However, an analysis of the pattern of energy consumption and energy subsidies exposes the distortions that have set into the system due to the lack of an integrated approach to energy pricing.

The discussion presented in the following pages addresses some of these issues

2. Review of Energy Pricing Mechanisms, Rationale and Trends

2.1 Coal pricing

Prior to the Government's intervention in 1944, coal mining was largely owned and managed in the private sector and product prices were set by forces of market demand and supply. During the period 1944-67, coal price revisions were linked to labour awards, this was followed by a phase of decontrol which lasted upto 1973 when the coal industry was nationalised. Since then, coal prices have been regulated and revised several times on the basis of the suggestions of Committees and Working Groups set up by the Government In general, all the committees have advocated that the pithead price of coal should be related to the industry-wise average cost of production with suitable allowance made for cost increases. Starting with the Fernandes Committee in 1973 right upto the price revision exercise presently completed by the Bureau of Industrial Costs and Prices (BICP)[1], a principle of 'cost plus' has been adopted for coal price fixation. The average cost of production is estimated for a sample of representative mines.

In spite of adopting a cost plus principle the coal producers have been incurring losses owing to an insufficient allowance for increases in input costs or delays in price adjustments.

Current procedure for coal pricing

The pithead price of coal is presently based on the average cost of production for the industry, differentiated between grades of coal depending upon properties such as ash content or useful heat value (UHV) The pricing procedure focuses only on the pithead or the mine head price with the delivered price of coal left largely uncontrolled.

The delivered price of coal to the consumer is determined by adding transportation costs, taxes, royalty payments and local cesses to the pithead price (Fig 1) Due to geographical concentration of coalfields in the eastern part of India, coal is transported over long distances Hence, the share of transportation costs in the delivered price (especially in case of non-coking coal) is quite high

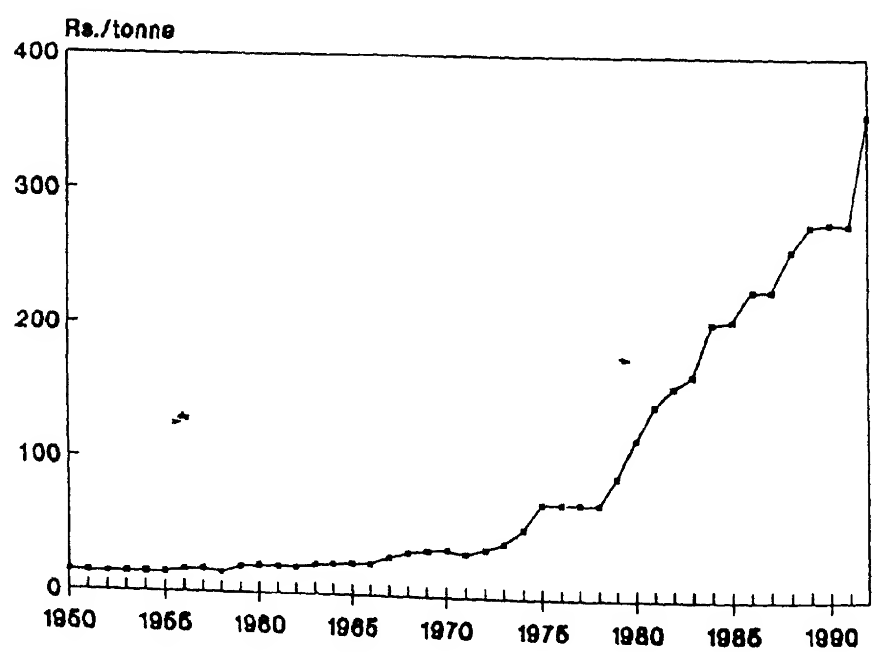
[1] BICP has been involved with coal price fixation since the early 1980s

Figure 1: Market price build up coal

Average cost of production for the industry
+
Loading cost
+
Handling cost

Pithead price
+
Washing cost
+
Transportation cost
- by rail
- by road
+
Royalty
+
Coal mines welfare organisation cess
+
Rescue cess
+
Stowing excise duty
- on coking coal
- on non-coking coal
+
Sales tax
- Central
- State
+
Local levies

Figure 2. Average pithead price of coal



Trend in coal prices

The behaviour of coal prices can be broadly categorized into two phases in time (refer Fig 2).

- the pre-nationalization period when coal prices remained fairly low and increases in them were steady The prices increased at a growth
- the pre-nationalization period when coal prices remained fairly low and increases in them were steady The prices increased at a growth rate of 3 5% during the 1950s 1950-60 and 5.6% during the 1960s.
- the post-nationalization period which witnessed a sharp rise in prices, registering an annual rate of growth of 12 8% during 1970-80 and 8.1% during 1980-91

The rapid escalations in the latter period are often attributed to factors such as the absorption of casual workers in the regular labour force leading to a higher wage bill, improvement in the bargaining power of labour due to unionization, de-linking of wage and labour productivity, increasing capital intensity of new mines and increasingly difficult geo-mining conditions leading to higher costs of production

In terms of relative prices of different grades, the revisions effected during the period 1979-85 had enhanced the differential between coking coal and superior non-coking coal on the one hand and superior and inferior non coking coals on another The intent was to avoid a sub-optimal use of good quality coal and encourage producers to improve the output mix. However, the subsequent price revisions made since January 1986 till date have narrowed the inter-grade price differentials In case of soft coke for domestic use there is a large element of subsidy. The pithead price has remained unchanged at Rs 175 per tonne since 1982 with view to protect the common man

Although the revisions are basically intended to provide an adequate remuneration to the producers (on account of rising costs of coal production), they have not kept pace with escalations in the costs, thus resulting in substantial losses accumulating in the coal sector. The cumulative loss in as on 31 March 1992 stood at Rs 2254 crores The Singareni Colliery Company Limited (SCCL), which accounts for about 20-25% of total coal production, the cumulative losses as on 31 March 1992 were of the order of Rs 624 crores

The coal prices at the pithead have been revised upwards by about 12-13% with effect from 17 February 1993 with a view to cover the escalating costs of major inputs The revised prices are expected to mobilise an additional revenue of Rs 924 crores for CIL and Rs 110 crores for SCCL during 1993-94

Some disquieting features of coal pricing in India. The present structure of coal pricing of CIL is not quite rational in the following respects:

- the pithead prices, which are related to the cost of production, have an in-built inefficiency in that these are calculated with total disregard for the low output per manshift (OMS), especially in case of the older mines. An analysis for non-coking coal reveals that if the productivity in case of all the less efficient mines were to increase to a level of average OMS for the new more efficient mines, the cost reduction on account of lower manpower costs would be at least 30%. These costs under the alternative scenarios of labour productivity are presented in Table 1

Table 1.
Economic cost of production of non coking coal at the pithead under alternative assumptions of OMS (Rs/tonne in 1990-91 prices)

	Case I	Case II
Underground mines	507	389
Opencast mines	295	226
Industry-wise average	369	283

Source Estimated

Case I Calculated on the basis of the present industry wise average OMS of 3 33 in case of opencast mines and 0 54 in case of underground mines

Case II Calculated on the basis of an average OMS for the new mines at 4 69 in case of opencast mines and 0 81 in case of underground mines.

- in the post-nationalization period the remuneration paid to labour has risen faster than labour productivity and, in fact, even higher than the overall escalation in the cost of coal production
- there is a glaring discrepancy observed in the present price structure of non-coking coal, whereby some of the inferior grades of coal are priced higher per unit of heat value as compared to the superior grades of coal This distortion is particularly noticeable in case of coal from Singareni coalfields of Andhra Pradesh (Annexure 1).
- there is no systematic or logical principle adopted for inter-grade price differentials A rational pricing structure should have an in-built

allowance to adequately compensate the consumers for using lower quality coal, which is not the case here

2 2 Petroleum pricing

The regulation of petroleum pricing dates back to the mid twentieth century It was in 1961, however, that earliest attempts were made to systematically regulate the prices of petroleum products These were based on the recommendations of the Damle Committee (1961) which was the precursor for a series of committees to be set up by the Government from time to time

Since, at that juncture, bulk of crude oil and petroleum products were being imported into the country, Damle Committee (1961) and Talukdar Committee (1965) recommended the 'import parity' principle for fixing the product prices The Shantilal Shah Committee (1969) suggested a change away from the import parity because the indigenous supply of crude oil was gradually gaining importance Nevertheless, the import parity had to continue owing to the 'refinery agreements' made with the foreign refining companies The Committee also made provisions for marketing margins and profits for each product on a normative basis

The principle of import parity persisted till 1976 when the Oil Prices Committee (OPC) recommended its discontinuance owing to a number of reasons - mainly that the import of products constituted less than 10% of total demand with future increases in demand to be met by domestic production and refining of oil And secondly, the posted prices of petroleum products from West Asia were not considered to be representative of the scale of operations and refining conditions in India

Alternatively, the OPC, 1976 recommended that pricing of petroleum products at refinery points be based on the domestic costs by taking into account the delivered cost of crude oil, refining costs and a reasonable return on the capital employed A similar concept was extended to cover the marketing and distribution activities as well Subsequently, the Oil Cost Review Committee (OCRC), 1984 also followed the principle of pricing based on costs plus return as suggested by the OPC, 1976

The recommendations of the most recent committee, that is, the Oil Prices Review Committee (OPRC) set up in 1989 differ from those of the OCRC in following respects

- a dual system of pricing for crude oil produced by the Oil and Natural Gas Commission (ONGC) and Oil India Limited (OIL) due to their different technical and cost structures Hitherto, these had been the same
- provision of a 12% post tax return on capital employed as against the existing 12% post tax return on net worth and a weighted average

interest on borrowing to the refineries This tantamount to treating both own and loaned funds at par

- increase in the prices of SKO (to bring it in line with that of HSD) and LPG
- abolition of subsidies on naphtha, FO and LSHS for fertilizer industry to encourage the use of natural gas as a substitute

Procedure for Petroleum Pricing

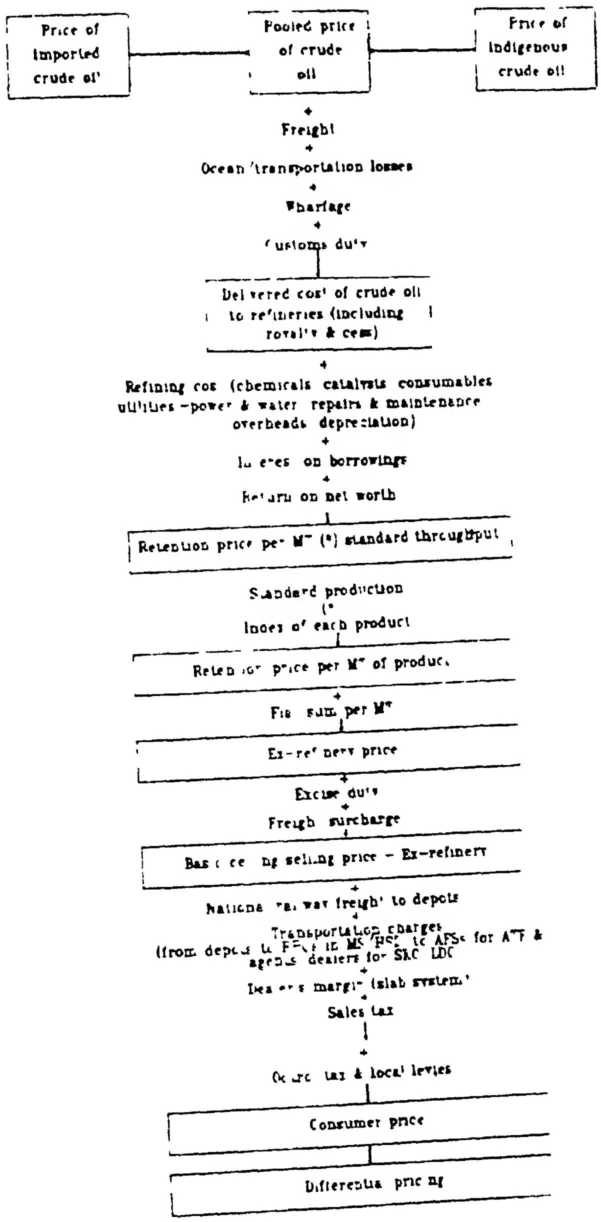
Petroleum prices are fixed by the government and revised from time to time for various stages of the supply industry Pricing of petroleum products is based on the concept of 'retention pricing', taking into account the delivered cost of crude oil, its refining costs and some reasonable rate of return on the capital employed The 'retention concept' is extended to cover distribution and marketing activities also (Fig 3)

Presently, the oil refining and marketing organisations are compensated as suggested by the OPC, 1976 and subsequently updated by the OCRC, 1984 in consultation with the Oil Coordination Committee (OCC) and accepted by the Government These prices are administered through a series of pool accounts The price of the resource i e crude oil, to be paid to the petroleum exploration and production organisations is decided on the basis of their cost of operation and a reasonable margin for expanding future exploration and production activities

The second stage involves 'transfer pricing' i e price paid for crude oil by refineries to the producers This is determined by means of pooling the prices of indigenous and imported crude oil and relates essentially to sharing of the 'economic rent' arising due to the use of an exhaustible resource between producing and refining organizations An account called the Crude Oil Price Equalisation (COPE) account was introduced, to which the processors of indigenous crude oil pay the difference between the pooled price of crude oil and indigenous price of crude oil, while the processors of imported crude oil claim the differential between approved price of crude oil and the pooled price of crude oil This is done in a manner that the refineries pay a uniform price for the crude which they process

The third stage pertains to 'output/product pricing' whereby the product-wise retention prices for refineries are set keeping in mind the product mix to be attained with respect to their demand, while ensuring the financial viability of the refining companies For apportioning the total refinery cost over individual products, a set of indices have been evolved whereby kerosene, a product of mass consumption, is used as the base and other products are related to it These indices are revised from time to time to take into account the prevailing demand and supply position in the country, ability of products to bear additional charges, need for cross

Figure 3 Market price build-up of petroleum



subsidization based on the end-use profile of products, international prices of various petroleum products and the need to favour production of certain products with a view to conserve foreign exchange Broadly, these indices are a reflection of the government policy objectives A similar concept is adopted for fixing retention prices for organizations engaged in distributing and marketing these products The cost of marketing operations is recovered by the oil companies through marketing margins recommended by the government appointed committees

Trend in petroleum prices

Crude oil prices

The movement in indigenous crude oil prices is fairly independent of the behaviour of imported crude oil prices (Annexure 2).

- despite sharp increases in crude prices, following the two oil shocks in 1973 and 1979, the domestic price adjustments were made in such a way so as to avoid sharp inflationary effects The price of domestic crude oil was maintained below the international price upto the year 1985-86 Subsequently, even though the imported crude prices decreased (following the slump in the international market in 1986-87) the domestic prices were maintained at a higher level
- while the price paid to the domestic crude producers such as ONGC and OIL has been kept constant at the 1981 level the delivered price of crude oil to the refineries has been increasing with the Government taking an increasing share of sales revenue by imposing higher rates of royalty and oil development cess The prices for domestic producers of oil are expected to be raised shortly to reflect their increased cost of production with reference to those in 1981 since when these prices have remained unchanged

Petroleum product prices

If one tracks back in time, upto October 1973 the prices of petroleum products were linked to changes in the price of imports, while insulating mass consumption products such as SKO, HSD and naphtha for fertilizers from the external oil market fluctuations Since 1974 the domestic prices have been largely based on the domestic cost of production with a differential pricing policy adopted to achieve cross subsidization or revenue generation for the Government and related to the import costs only to a limited extent

A comparison of product prices in the period 1970-71 to 1990-91 shows sharply rising prices of FO (14.7%) followed by relatively lower increases in the prices of MS, LDO, ATF and lubricants that is, in the range of 10% to 13% The lowest rates of price rise, in the range of 8% to 9% were observed in case of SKO which is meant for cooking and lighting amongst the poorer

sections of the society and HSD, which is used as a fuel in the public modes of passenger and goods transport (Figures 4 and 5)

In general, the petroleum prices have been revised on account of the following factors

- mobilization of resources for the petroleum sector or financing the planned development of the economy
- compensating for higher costs of imports either due to an increase in the international prices or the devaluation of the Indian rupee
- sometimes improvement in the balance of payment position and demand curtailment are also held responsible for an increase in the prices of some products, although the latter has not met with much success

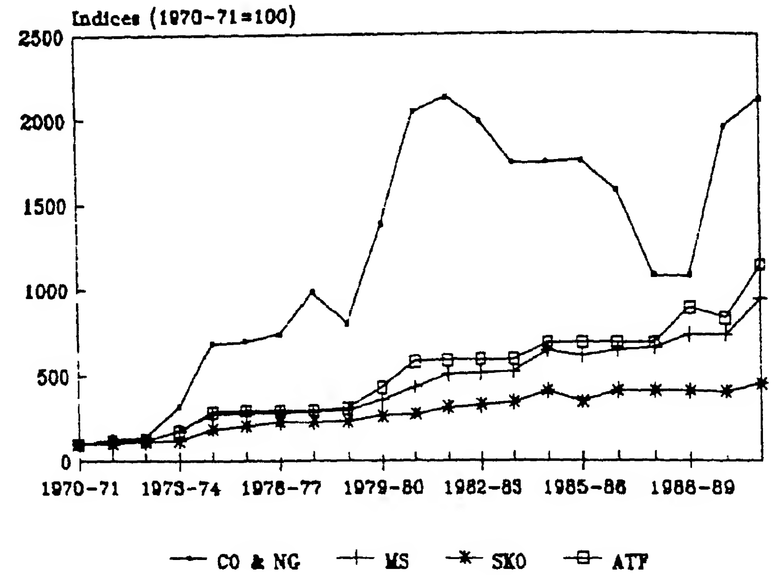
The prevailing pricing policy, guided by short term objectives coupled with inadequate administrative supervision, has led to several distortions in consumption such as adulteration of diesel with kerosene in the transport sector, diversion of domestic LPG for commercial and even transportation purposes, lower substitution of naphtha and FO/LSHS by natural gas in the fertilizer industry owing to the concessional prices of the former

2 3 Electricity pricing

Electricity pricing in India lies within the purview of the State Electricity Boards (SEBs) As per the Electricity (Supply) Act 1948, the board has to carry on its operations, as far as practicable, without incurring losses and it could, from time to time adjust its tariffs The Act, however, did not mention any surplus that the board was expected to earn The objective of the pricing policy was to encourage the use of electricity for the growth and development of the economy

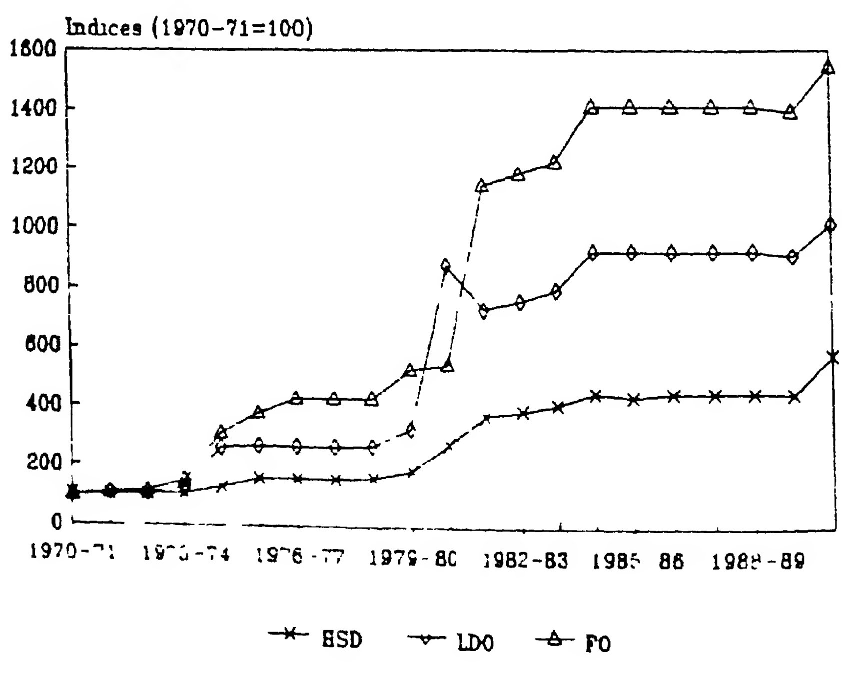
The Electricity (Supply) Act was amended in 1978 to make SEBs commercially viable and to earn a net rate of return on their investments In accordance with the amendment, the SEBs were to carry out their operations and adjust tariffs so as to ensure that total revenues in any year generate surpluses as specified by the respective state governments There was another amendment to the Act in 1980, which specified that the SEBs should earn a net return of 3% on net fixed assets (as at the beginning of the financial year) after the payment of interest and provision for depreciation In practice, however none of the state governments impose a mandatory rate of return on the SEBs and most of the SEBs in the past years have been unable to achieve the prescribed rate of return of 3% (refer Annexure 3)

Figure 4: Trend in the wholesale price of petroleum products (1970-71 = 100)



CO-Crude oil, NG-Natural gas

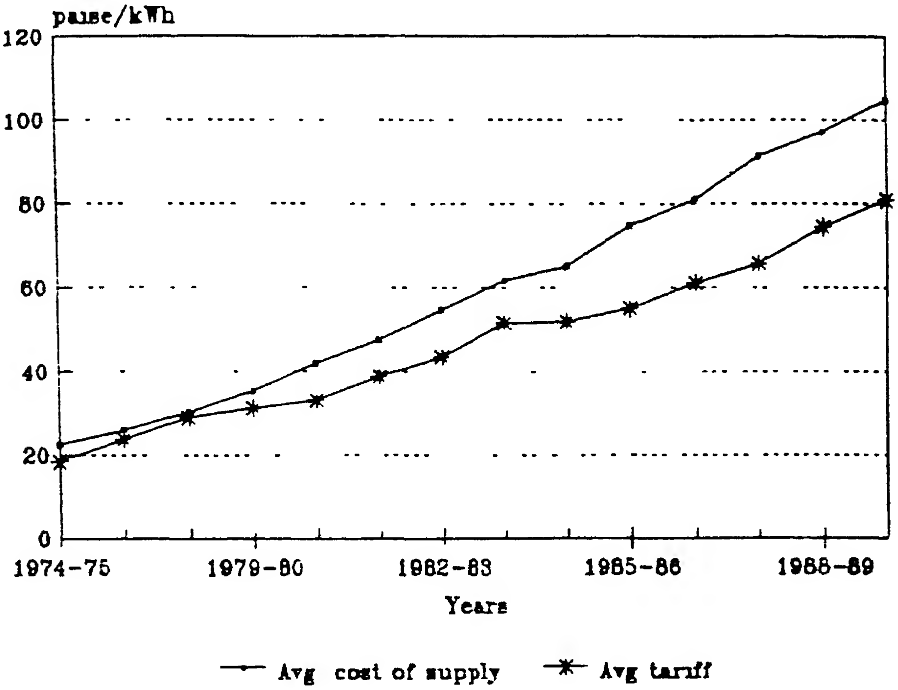
Figure 5: Trend in the wholesale price of petroleum products (1970-71 = 100)



Current procedure

Pricing of electricity by the SEBs has generally been based on the principle of recovering the average cost of supply In practice, however, the boards have been unable to recover their overall average cost of generation and supply, and the deficit has increased overtime At the national level, per unit revenue loss increased from 4 13 paise/kWh in 1974-75 to 8 67 paise/kWh in 1980-81 and further to 24 7 paise/kWh in 1990-91 (refer Figure 6)

Figure 6: Trend in average cost of supply and average tariff



All the SEBs follow a policy of differential pricing for the supply of power to different consumer categories While laying down the tariffs, the SEBs have to take into consideration the policies and objectives of their state governments Tariffs are often weighed more by social and political considerations rather than financial and economic efficiency objectives Tariff revisions are generally carried out on an adhoc basis The sole criterion is the absorption capacity of the consumer without causing an agitation The additional costs to be recovered are calculated first, based on which the extent to which the rates for high tension consumers can be raised is decided The balance cost to be recovered is then adjusted to the extent possible from the low tension industrial, commercial and domestic

consumers. The tariffs for the agriculture sector are reported to have a strong linkage to political considerations.

Tariff structure
Most of the SEBs charge an energy rate (paise/kWh) for the energy supplied to the low voltage consumers namely, domestic, commercial and LT-industries. For high voltage consumers the SEBs generally have a two-part tariff - a demand charge based on the maximum demand reached during the billing period and an energy rate. A point to be noted is that the demand charge is not related to the incidence of the occurrence of maximum demand and therefore does not provide any incentive for load management. Increasing block tariff is perhaps the only pricing measure adopted by the boards to encourage energy conservation.

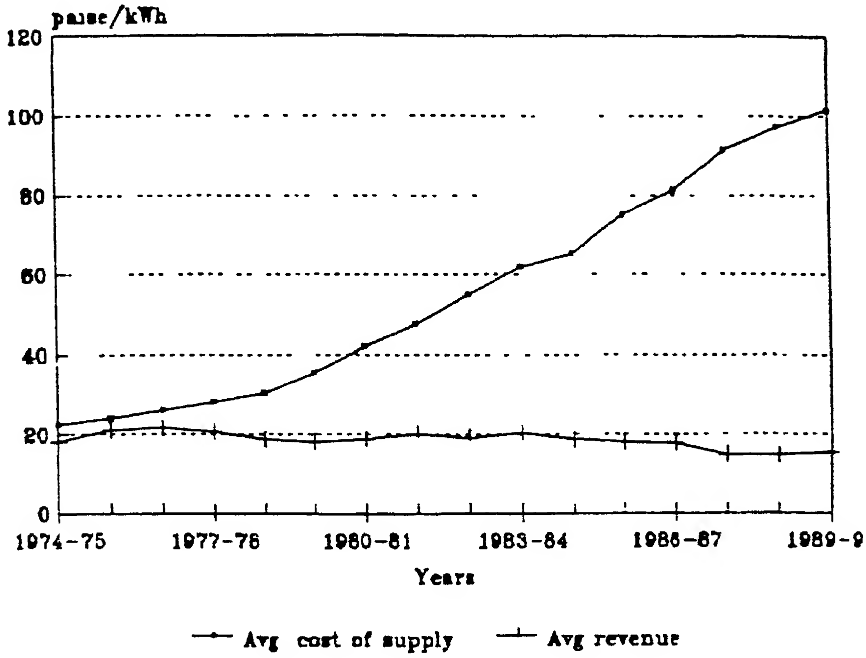
All the boards have a fuel adjustment clause built into the tariffs. However, the increases in fuel costs are generally passed on selectively to some consumer categories. Domestic, agriculture and LT-industries are often not subject to the fuel adjustment charge. Another important element of the tariff structure is the 'power factor correction charge' for maintaining the power factor for HT-consumers, and in some cases for LT-industries as well. While most of the boards have a penalty for the low power factor some of the boards offer an incentive for improving the power factor.

Trends in electricity prices
Electricity prices are lowest for the agriculture sector and over the years the gap between the cost of generation and supply and the average realisation from the agriculture sector has been widening (refer Figure 7). Utility-wise analysis shows that during the period 1985 to 1990, out of 22 utilities in the country, electricity tariffs for agriculture consumers declined in 5 utilities and remained unchanged in 13 utilities (Annexure 4). Consequently the losses at the All-India level which are incurred on account of supply of electricity to this sector have increased at a compound annual growth rate of 25% during the period 1985-86 to 1990-91. One of the reasons for the decline in the average agriculture tariff since mid-seventies is the fact that all the SEBs gradually changed over from metered supply to "flat-rate" tariff based on the connected load (HP of pumpset), primarily due to administrative conveniences, and reduced cost of billing and collection. This, however, has encouraged misuse and wastage of electricity, there are several instances of farmers running small industries on agricultural connection. Moreover such un-metered supplies makes it impossible to measure the distribution losses of electricity in the system.

The Central Government, in view of the increasing losses of the boards on account of supplying power to the agriculture sector, has recommended

a minimum 50 paise/kWh rate for sale of electricity to the agriculture sector However, so far only a few utilities have implemented this

Figure 7: Trend in average cost of supply & average realisation from agriculture sector



The average tariff for the domestic sector also continues to be below the average cost in all the SEBs In 1990-91 the average domestic tariff was subsidised more than 50% in 8 out of 18 SEBs During the period 1985-90, domestic tariff for consumption less than 30 kWh/month, declined in 2 utilities and remained unchanged in 6 utilities In 1990-91, the estimated All-India losses on account of subsidised electricity supply to the domestic category was Rs 1056 crores

In order to partially make good the losses that SEBs incur as a result of subsidy provided to agriculture and domestic consumers, industrial and commercial consumers are often charged a rate higher than the average cost of supply to them Also in case of any tariff revision maximum burden is passed on to these two consumer categories 'all the SEBs have a 'fuel adjustment clause' for the industrial and commercial sector Some of the SEBs such as HPSEB KSEB TNEB etc, where the growth rate of tariff increase in agriculture and domestic sector was quite small during the period 1985-90, the tariff for commercial and industrial sector increased at a significantly high rate During this period the average tariff increased more than 10% in 15 utilities for small and medium industries and in 20

utilities for large industries For the commercial sector annual growth rate ranged between 6-8% during the same period

2.4 Natural Gas pricing

Natural gas is emerging as an important source of energy, primarily to supplement petroleum products whose deficits are predicted to rise in the years ahead Prior to January 1987, natural gas prices were fixed in an adhoc manner and revised from time to time by the gas producers on a locational basis Subsequently, a committee was set up by the Government of India to look into natural gas pricing, which submitted its report in January 1987 The Committee recommended that natural gas prices for the consumers should be set in a manner that there was a parity between them and the prices of fuel/feedstock which would get replaced by natural gas Further, with the exception of fertiliser industry the prices for other consumers were to vary along the HBJ pipeline in order to account for the cost of transportation Owing to the centralised subsidy scheme, a uniform price was suggested for the fertiliser manufacturers. Concessional prices were also recommended for the north-eastern region

For the producers, the committee was of the view that prices should be fixed on the basis of cost of production from the South Bassein gasfield and cost of transportation along the HBJ pipeline However, the prices finally approved by the government were based entirely on the cost of production from South Bassein, with no distinction made between producers' and the consumers' prices The following price structure, exclusive of royalty, taxes, duties and other levies was adopted in 1987

(i) Rs 1400/1000 m^3 for gas at landfall points for onshore gas

(ii) Rs 850/1000 m^3 as transportation cost for gas supplied along the HBJ pipeline.

(iii) Concessional rate of Rs 1000/1000 m^3 for gas sold in the north-eastern region, subject to discounts upto Rs 500/1000 m^3 in view of the low level of demands

In view of the growing importance of natural gas, in March 1989 another committee, under the chairmanship of Dr V Kelkar, was set up to look afresh into the issues related to natural gas pricing The Committee recommended that the price of natural gas to the producers should be linked to the long run marginal cost of production from the South Bassein gasfield with a 15% rate of return on investment Consumer price was to be based on the principle of opportunity cost The transportation cost along the HBJ pipeline was estimated at Rs 850 1000 m^3 and was proposed to be uniform along the HBJ pipeline For the north-eastern states concessional prices were recommended to promote the use of natural gas The difference between the producer's and consumer's price was to be credited to the gas

pool account which would be maintained by the Department of Petroleum and Natural Gas to be used for the general development of the gas industry.

The recommendations of the Kelkar committee have been partially accepted by the government and natural gas prices have been revised as follows with effect from 1 1 92

(i) Rs 1550/1000 m^3 for gas at landfall points and for onshore gas. This price would be revised by Rs 100/1000 m^3 at the end of each year for a period of three years

(ii) Rs 850/1000 m^3 as transportation cost for gas supplied along the HBJ pipeline The cost of natural gas along the HBJ pipeline would correspondingly be Rs 2400/1000 m^3 w e f 1 1 1992

(iii) The cost of gas in the north-eastern region would continue to be Rs 1000/1000 m^3, but subject to discounts upto Rs 400/1000 m^3.

(iv) The revised prices would be charged for natural gas with a calorific value range of 9000-9500 Kcal/m^3 Rebate/premium will be levied on gas having a lower or higher value than the specified range

3. Impact of prices on fuel demand

According to traditional economic theory, demand is a multivariate relationship, i e , it is determined by many factors such as the price of the product, consumer's income, prices of related commodities and consumer's tastes The law of demand states that, ceteris paribus, (other factors remaining unchanged) market demand is negatively related to its price However, in case of the Indian energy sector, the traditional theory of demand may not hold good owing to widespread physical shortages in the supply of fuels as well as the prevailing administered price regimes In view of scarcity of specific commercial fuels the fuel demand function would be misleading in that the demand would get determined by supply and therefore the market demand curve would actually represent the supply curve

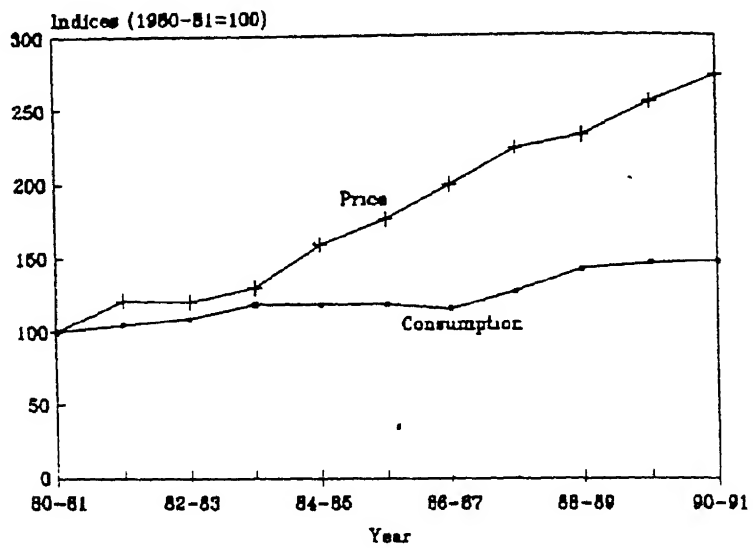
Nonetheless, an analysis of the demand-price relationship was carried out for the three commercial fuels, namely coal, petroleum and electricity, and the results are presented below

3 1 Coal prices and demand

The impact of price increase on coal demand was studied only for the power and steel sectors, since these two sectors account for a about (68-70%) of coal consumed in the country The consumption of power and steel grade coals was analyzed in relation to the average pithead price In case of non coking coal, the price was a weighted average of the pithead price of grades D, E, F and G which are predominantly used for power generation In case of coking coal it was the average pithead price of the washery grades I, II, III, and IV The time series data on coal consumption along with the average prices are shown graphically in Figures 8 and 9

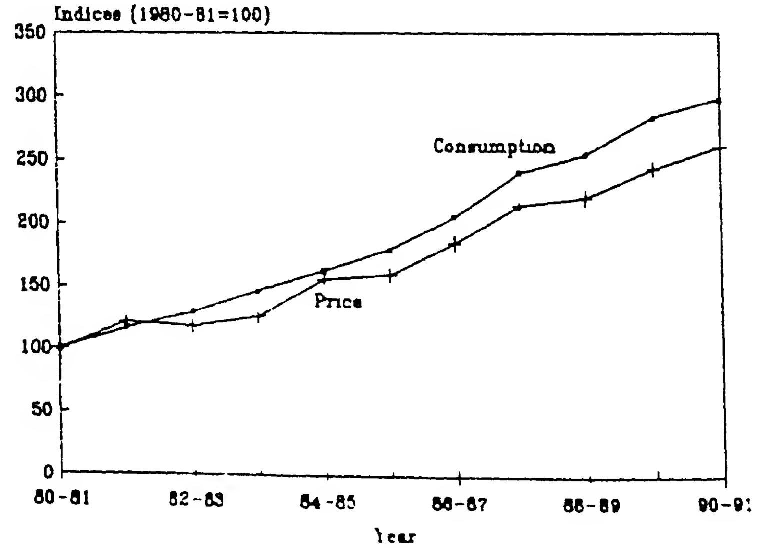
The demand for both power and steel grade coals has been in excess of their domestic supply which has resulted in a less than full demand satisfaction in case of the former and rising imports of coking coal for the steel industry (Annexure 5) An unsaturated demand will not be responsive to price changes This was also supported by the trend in demand and price of coal (Figures 8 & 9) In general, the coking coal demand and its price have depicted a rising trend in the last decade, with the rate of price increase of both being almost the same in the period 1980-81 to 1983-84 This was followed by a period of stagnation in its consumption at about 25 mt between 1983-84 to 1985-86 while the price registered a steep increase Thereafter, both demand and price rose at the same rate upto 1988-89, after this the slope of the price line became steeper than that of the consumption line implying sharply rising prices right upto 1990-91 Similarly, in case of power grade coal both demand and price delineate a rising trend with the absence of an inverse relationship in any of the time periods under study

Figure 8: Trend in coking coal demand and price (steel industry)



Price refers to the average pithead price

Figure 9: Trend in non-coking coal demand & price (power sector)



Price refers to the average pithead price

Quite unambiguously, the conventional demand-price relationship does not hold for both coking and non coking coal

3.2 Petroleum product prices and demand

The analysis to assess the impact of petroleum prices on demands was carried out by observing the data on monthly sales of major products and their ex-storage prices (at Bombay) in the four year period from 1988-89 to 1991-92 Considering that most petroleum products are being imported at the margin it is doubtful (as in case of coal), whether any meaningful conclusions can be drawn about the response of petroleum demand to price changes The results of the analysis are presented below

The monthly data on sales and prices of selected petroleum products are represented graphically in Figures 10 to 13 for LPG, MS, SKO and HSD respectively

LPG The price of LPG remained constant at Rs 3 45/kg upto July 1991 after which it increased by 20% to Rs 4 14/kg LPG sales registered an increase over the years with fluctuations on a month to month basis Following the price increase in July 1991, the sale of LPG did fall marginally from 220 thousand tonnes in August to 208 thousand tonnes in September 1991, after which it picked up to follow the general rising trend Considering that the sale of LPG had shown a decline in some months when the prices had remained unchanged, it would not be correct to conclude that the downward trend in sales in September 1991 can be attributed entirely to the price increase (Fig 10)

Petrol (MS) Between 1988-89 and 1991-92, the aggregate sale of petrol/mogas fluctuated significantly on a month to month basis with some growth in the overall demand Corresponding to each of the price revisions made in March 1990, October 1990 and July 1991, there were characteristic reductions in the sales volume However, these reductions were temporary and the demands gradually recovered to follow the general trend (Fig 11)

Kerosene (SKO) The sale of SKO also witnessed a fluctuating trend while the price for the domestic sector[2] was kept constant at Rs.2 25/kg till March 1990, after this it was raised by 25% to Rs 3 14/kg only to be reduced again in July 1991 to Rs 2 83/kg (Fig 12) The recent price revision in September 1992 has increased the prices of all the petroleum products, with the exception of SKO An analysis of the data leads us to conclude that with an increase in SKO prices its sales did not show a decline, and with a lowering of the prices the demand increased Considering the large fluctuations observed in SKO sales it is debatable whether this increase can be attributed to lower prices

[2] According to official statistics about 90% of SKO is consumed in the domestic sector

Figure 10: Trend in sales of LPG vis-a-vis ex-storage price

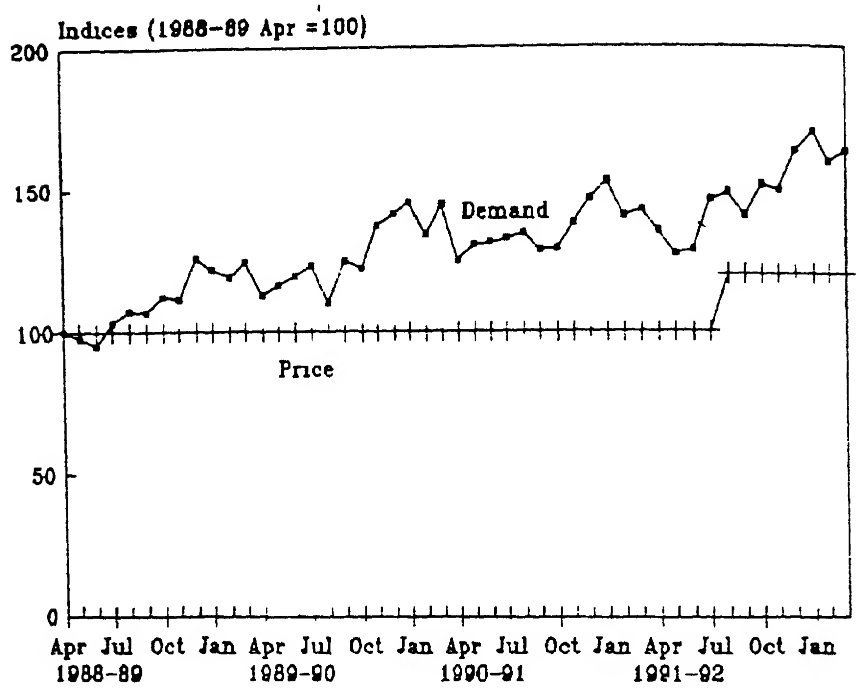


Figure 11: Trend in sales of MS vis-a-vis ex-storage price

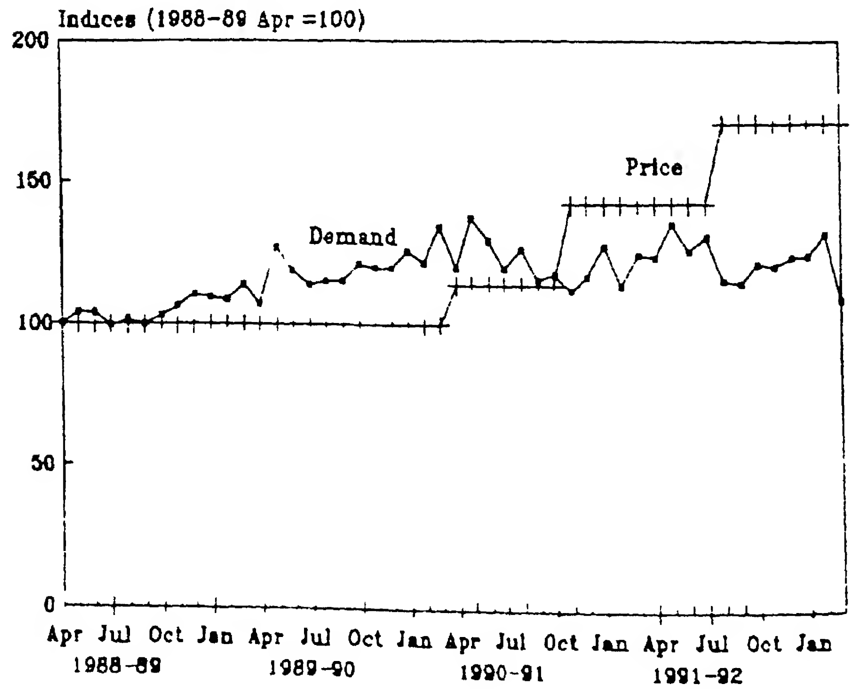


Figure 12: Trend in sales of SKO vis-a-vis ex-storage price

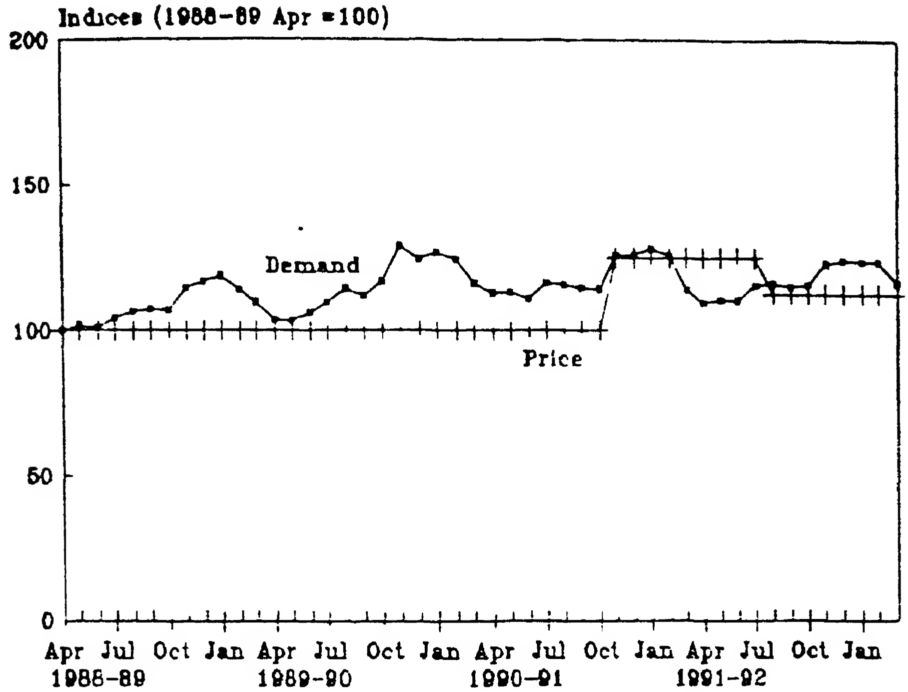
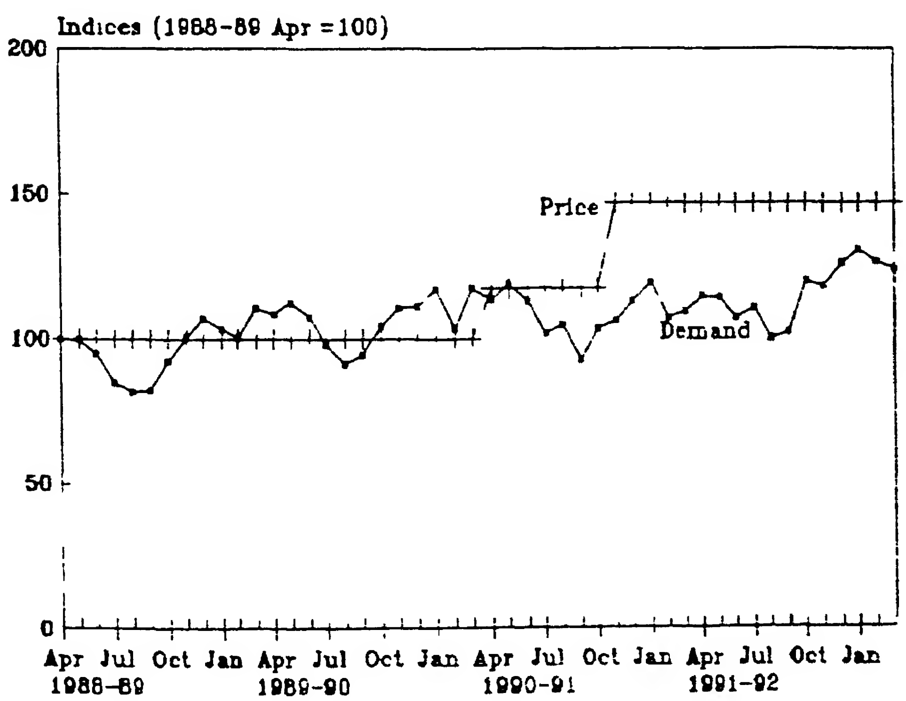


Figure 13: Trend in sales of HSD vis-a-vis ex-storage price



Diesel (HSD) The price increases in HSD were effected in March and October 1990. On the other hand, the demand for HSD has risen slowly over the past four years with marked instability from one month to another There have been reductions in the quantity sold despite the stability in prices such as in the period from May 1988 to September 1989 and February 1991 to August 1991 Thus, no clear conclusion can be drawn about the behaviour of HSD demand with respect to prices changes (Fig 13)

In general, no conclusive inference can be drawn about the impact of energy price changes on demand to support the traditional economic theory of demand

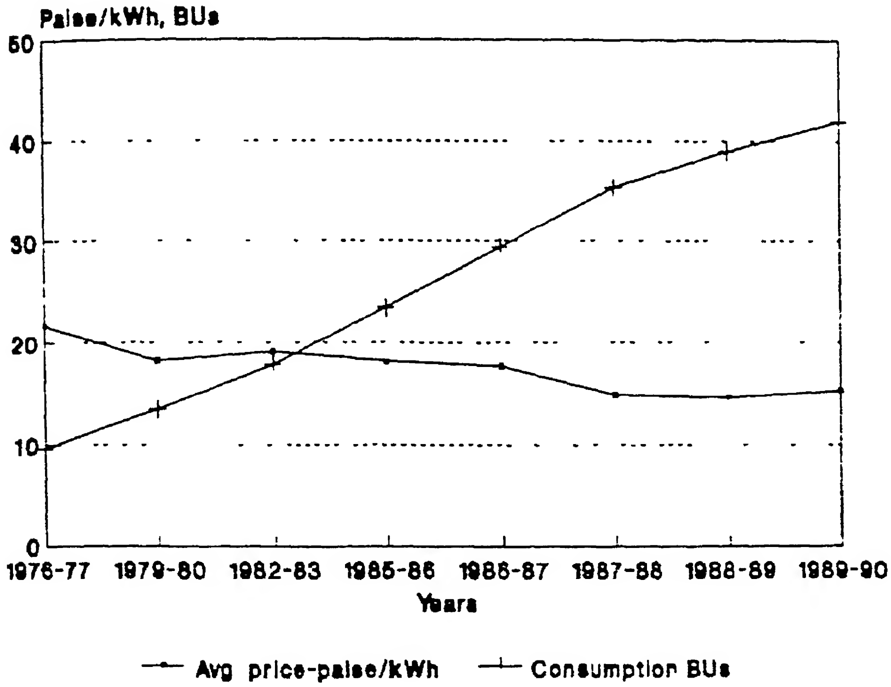
3.3 Electricity

In case of electricity, it is difficult to analyze the impact of prices on consumption at the national level for different consumer categories This is not only due to significant differences in tariffs across the states, but also because the revisions in any state are guided more by the state government's socio-political objectives rather than the financial or efficiency criteria

The most obvious impact of tariff revision on electricity demand can be observed in the agriculture sector Not only are the tariffs for the agriculture sector low but have, in fact, declined since the mid seventies This has resulted in a high growth in the consumption of electricity for irrigation purposes with the share of electricity sales to this sector increasing from near 14 5% in 1975-76 to almost 25% in 1990-91 (Fig 14) In the domestic sector also the low electricity prices have encouraged consumption

Electricity tariffs are the highest for industrial consumers and have risen sharply over the years compared to those charged to other consumer categories All that can be observed is that the share of industries in overall consumption has declined from 62 4% in 1975-76 to 47% in 1990-91 However, it is difficult to determine the extent to which high electricity prices are responsible for this declining share Factors such as high growth rate of electricity consumption in agriculture and domestic sectors and improvements in energy efficiency in the industrial sector are also responsible for the decline in the share of electricity consumption in industries Further, it is important to note that electricity consumption is not a true reflection of demand for electricity, particularly in the industrial sector where the power cuts are the highest amongst all the consuming sectors

Figure 13: Trend in agricultural tariff & consumption



3 4 Natural Gas

In the absence of a reflection of the relative end-use efficiency in natural gas pricing vis-a-vis other substitutable fuels there has been a significant increase in the demand for natural gas and administered inter-sectoral allocations of gas have been resorted to without fully taking into account the economic considerations

4. Comparison of economic price (EP), market price (MP) and border price (BP)

Energy prices, as they are currently set in India, do not reflect the true cost of supply to the consumers nor do they take into account the impacts of a particular price structure in one of the energy sub-sectors on the other energy sub-sectors Bearing this in mind, an attempt was made to estimate the economic price of coal, oil, electricity and natural gas and compare these with the respective market prices and border prices

To begin with, a comparison of prices was made for individual fuels This was followed by an integrated analysis to assess the (i) cost per unit of useful energy for each fuel in specific end-uses, and (ii) the extent of subsidies and taxes resulting from the difference between the EP and MP The base year of analysis was taken as 1990-91

4 1 Coal

A comparative analysis of the EP and the MP showed that, at the pithead, the EP was about 21 5% higher than the MP in case of non-coking coal (grade D) and about 9% higher in case of prime coking coal Thus, the coal producing companies incur a loss on account of production of these coals However, in case of medium coking coal, the EP is lower than the MP implying that the selling price will bring in a positive return to the producers (Table 2) Details of these are given in Annexure 6

Table 2.
Comparison of economic price, market price and border price of coal at pithead

(Rs/tonne, 1990-91 prices)

	Non-coking		Coking	
	Grade A	Grade D	Prime coking	Medium coking
Economic price		310	882*	441*
Market price (pithead)	402	255	811*	802*
Market price inclusive of royalty cesses and taxes	600	383	1100*	982*
Border price**	1528		1848	

*These are inclusive of the cost of washing
**These refer to the c i f price at the port of landing
Source Estimated

If we were to compare the prices at the consumer's end then even in case of non coking coal and prime coking coal, the MP was found higher than the economic cost of supply This was largely because of the inclusion of transport costs and imposition of royalty, cesses, excise tax and other levies to arrive at the delivered price This implies that while the railways and the Government are generating revenues from the sale of coal, the coal companies are not being paid remunerative prices to recover their cost of production. In the case of non coking coal and prime coking coal the MP is about 20-25% higher than the EP while it is about twice as high in case of medium coking coal However, there is a high subsidy on soft coke (about 50%) when its price is compared with the cost of supply of the smokeless fuel (Table 3)

At present India is only importing good quality coking coal from Australia for use in the steel plants However, if we were to import superior steam grade coal the representative BP would be that of steam coal from Australia In case of both steel grade and steam coals, the border prices were observed to be much higher than the market prices both at the point of landing and at the consumer end Moreover, the price differentials were much higher in case of superior steam coal as compared to prime coking coal (Table 3)

Table 3.
Comparison of economic price, market price and border price of coal at the consumption point (Rs/tonne, 1990-91 prices)

	Non-coking*		**Coking***		**Soft coke**
	Grade A	Grade D	Prime coking	Medium coking	
Economic price		541	1023	582	938
Market price	899	682	1225	1108	467
Border price**	1857		2138		

* The average lead distance for transportation of non-coking coal is taken as 750-1000 kms and for of coking coal as 250-500 kms

** These are inclusive of the cost of port handling and transportation to the consumer

Source Estimated

4 2 Petroleum

The retail selling prices of selected petroleum products (at Delhi) were compared with the EP calculated for the distance slab of 750-1000 kms by rail and road (the average lead distance of petroleum products lies in this

distance range) In case of petroleum, the EP is also the BP since the former was computed on the basis of the c i f price of individual products (refer Annexure 7 for details) It was observed that while MS and ATF (to domestic airlines)[3] are heavily taxed products, with the tax level of the order of 133% and 111% respectively, the tax on FO (for non-fertiliser use) is relatively lower, i e in the range of 20-23% However, HSD, SKO and LPG were subsidised with the level of subsidy being 20% on HSD and about 58% in case of both SKO and LPG

Table 4.
Comparison of economic price and market price of petroleum products to the consumer for a distance slab of 750-1000 kms

(Rs/Litre, 1990-91 prices)

	Economic price (by rail)	Economic price (by road)	Retail selling price (at Delhi)
MS	4 21	4 49	9 83
ATF (domestic airlines)	3 17	3 47	6 70
HSD	5 11	5 44	4 07
FO (non-fertilizer use)	2 65	3 02	3 25
SKO	5 40	5 71	2 25
LPG	9 78	10 17	4 06

Source Estimated

4 3 Electricity

As mentioned in the above section, it was difficult to compare the MP and EP of electricity at the All-India level, since tariffs vary considerably across the states Therefore the comparison of MP and EP of electricity was carried out for the Maharashtra State Electricity Board (MSEB) as a case study

The EP of electricity was its long run marginal cost (LRMC) of generation and supply The flow chart given in Annexure 8 depicts the methodology for calculating the LRMC based tariffs A comparison of marginal cost, average cost and average revenue realised for different

[3] under the international agreement ATF is supplied to international airlines at subsidised prices

categories for MSEB is presented in Table 5 below The important points that emerge are

- all consumer categories except HT-industries are supplied power below the marginal cost of generation and supply to them
- the extent of subsidy is highest in the agriculture sector - almost 90% compared to the marginal cost and 85% compared to average cost of generation and supply

Table 5.
Comparison of average revenue, average and economic prices for MSEB in 1990-91

Consumer category	Avg. revenue realised (p/kWh)	Average cost of generation and supply (p/kWh)	LRMC based tariff (p/kWh)
Domestic	71	114 41	149
Commercial	147	114 41	163
Agriculture	15	114 41	131
LT-industries	114	114 41	136
HT-industries	158	114 41	97

- domestic consumers pay only 48% and 62% of the marginal and average cost of generation and supply to them
- commercial consumers and LT-industries pay a rate higher than the average cost but are subsidised compared to their marginal cost The extent of subsidy is estimated at 10% and 16% respectively for commercial sector and LT-industries
- electricity supply to HT-industries is taxed, compared to both average and marginal cost

4 4 Natural Gas

The EP of natural gas was based on average incremental cost (AIC) of producing gas from the South Bassein gasfield, which would be one of the largest gas producing fields in India in the next few years The AIC was calculated separately for the gas production, transportation and distribution activities The cost of production includes investments and operating costs of gas exploration, production, sweetening and transportation Details of the AIC of production of natural gas are given in Annexure 9 The economic cost of production of natural gas was estimated at Rs 1260/1000m^3 as against the MP of Rs 1400/1000^3 in 1990/91 The economic cost of transportation

of gas along the HBJ pipeline was estimated as Rs 887/1000m[3] (assuming that capacity utilization of the pipeline would be 90%) Thus, as per the estimates for the year 1990-91, the consumer was charged a tax on natural gas consumption (Table 6)

Table 6.
Comparison of economic price and market price of natural gas in 1990-91

	Economic	Market Price
Production	Rs 1260	Rs 1400
Transportation	Rs 887	Rs 850

The use of gas as a substitute for other fuels/feedstock in industry and other sector may provide a different economic value to the consumers The replacement value of gas is the price of gas at which the unit cost of production of the final product will be the same as the unit cost of production based on the alternate fuel/feedstock in each of these sectors The replacement value of natural gas in major consuming sectors is presented in Table 7 It is evident that the market price of natural gas is lower than the replacement value of natural gas in case of both fertilizer and the power generation Such a pricing structure will lead to an excess demand for natural gas as the consumers would like to shift to gas instead of other fuels or feedstocks

Table 7.
Replacement value of natural gas in major consuming sectors

Sector	Economic replacement value (Rs./000m³)	Financial replacement value (Rs./000m³)
Fertilizers		
Case I[1]	2784	2495
Case II[2]	3258	2951
Power		
Case I[3]		
- pithead	1917	1942
- 500 km	2289	2503
- 1000 km	2519	3024
Case II[4]		
- pithead	2196	2199
- 500 km	2567	2760
- 1000 km	2797	3280
Case III[5]	2032	

(1) Gas based and naphtha based fertilizer plants assumed to operate at a same level of 80% capacity utilization

(2) Gas based power plants assumed to operated at a higher level of 90% of capacity utilization

(3) Both gas based and coal based power stations operate at a PLF of 62 79%

(4) Gas based power station operate at a higher PLF of 79 91% as compared 62 79% for coal based power stations

(5) Natural gas replaced fuel oil in a thermal power station, both operating at the same PLF

In case of natural gas, given the shortages that are foreseeable, even in the short run, prices should be linked to the economic replacement values in different end-uses However, since differential prices would lead to difficult issues of monitoring the consumption of natural gas for different consumers and end-uses, thus leading to problems of implementation, price discrimination among various sectors is not recommended However, the AIC of production and the economic replacement value of natural gas should be considered as the floor and ceiling respectively, and the market price be set between these two levels It is recommended that the price of natural gas should be equated to the fuel oil equivalent price of natural gas, which is estimated to be lowest among various replacement alternatives considered

5. Integrating social and financial considerations in the efficient price structure

In this section a simple matrix framework is developed to enable an analysis of the two price regimes (one based on the EP and the other on MP) in terms of the (i) price signals sent to the consumers, and (ii) taxes charged and subsidies extended to each of the energy consuming sectors for different fuels The product of the fuel price (both economic and market) and the efficiency matrix of fuel consumption in specific end-uses, gives the price per unit of useful energy for each end-use using alternative fuels The end-use price matrix, based on economic prices, gives the actual economic cost of providing a unit of useful energy by using alternative fuels, whereas the useful-energy price matrix based on market prices gives an indication of the signals being sent to the consumers

The next step in this framework is the development of a consumption matrix which has a structure similar to the efficiency matrix but has as its elements the actual consumption of various energy forms in specific end-uses If detailed information on consumption of various fuels for specific end-uses broken up further by income classes as well as the price elasticities of energy demand of the population in these income classes were available, it would be very simple to look at the social implications of alternative market price regimes In the absence of this information, all that can be derived are the broad directional changes that are expected in demand if energy tax/subsidy structures were altered The product of the consumption matrix and the price matrix, based on economic and market prices, gives an indication of the desired (or required) vis-a-vis actual realization by sectors of consumption and by fuel type The difference in these two values would indicate the extent of tax/subsidy accruable to various sectors and fuel types

The result of the integration are tabulated below while detailed calculations are provided in Annexure 10 The important observations which emerge are

1 All the commercial fuels consumed by the domestic sector are provided at a subsidized rate In terms of price per unit of useful energy, electricity is the cheapest option for lighting purposes and the energy efficiency increases almost 5 times if incandescent bulbs are replaced by fluorescent tubes The use of SKO for lighting purposes should be discouraged

   For cooking purposes, electricity works out to be almost 2-2 5 times higher compared to LPG in terms of useful energy The closeness of useful economic prices of kerosene and LPG brings out the sensitivity of the relative prices of these two fuels to the efficiencies assumed for kerosene stove If all the consumers were to utilize efficient cookstoves

(55% efficiency instead of the present level of 45%), the use of kerosene would turn out to be significantly cheaper compared to LPG for cooking and water heating.

2 In the industrial and commercial sectors the end-uses which have been considered are process heating and lighting It is evident that the use of non coking coal is cheaper than that of oil and natural gas for process heating purposes, despite significantly higher efficiencies of the latter two fuels This reinforces the findings of several committees which have pointed to the desirability of switching over to coal from fuel oil in the industrial sector The use of electricity in the commercial and LT industrial sector is subsidized marginally while it is taxed for HT industrial consumers

It is seen that all the three alternatives, viz coal, fuel oil and natural gas consumption in this sector are taxed Total negative subsidy in this sector is estimated to be about Rs 7650 crores The use of electricity in the commercial and LT industrial sector is subsidized marginally

Table 8.
Total energy subsidies in different sectors
(1990-91, Rs crores)

Sector	Subsidy (+)/Tax (-)
Domestic	6026 15
Industry & Commercial	-7649 86
Transport	-672 63
Agriculture	5373 97

3 The end-use price matrix of the transportation sector brings out the trade-offs between road and rail sector for both freight and passenger movement The cost of rail transportation (HSD) in case of freight movement are roughly a sixth of the costs incurred if one was to move commodities by road On the contrary, there is an increasing trend towards freight movement by road, indicating the willingness of consumers to pay for an efficient and reliable transport service In the case of passenger transportation, this difference is not as marked Here the use of electricity in the rail transportation while the cost of passenger transportation by cars works out to be much higher compared to other modes

The transport sector is also a revenue earning sector for the Government The total negative subsidy to this chapter is approximately 670 crores

4 Energy supply to the agriculture sector is heavily subsidized Although in gross energy terms diesel is cheaper than electricity, in useful energy terms electricity is significantly cheaper compared to diesel use High subsidies in the electricity sector has encouraged the farmers to move over to electric pumpsets and the diesel pumpsets are used only as stand-bys The number of electric pumpsets energised in the country have increased at a compounded rate of 9 1% during the period 1970/71-1988/89

5 As per the above analysis, a comparison of the EP with MP of selected fuels which are considered, the total subsidy to the energy sector works out to be about 3000 crores in 1990-91

6. Rationale for subsidies and consumer choices

At the outset we stated that on account of overriding concerns of social and political nature, the government imposes taxes or provides subsidies on fuels in such a manner that fuel prices do not reflect the real resource cost of their supply Invariably the level of subsidies/taxes are arbitrarily determined leading to distorted choices in consumption The discussion on the rationale and impacts of subsidies in case of specific fuels presented below

Subsidy on Kerosene The selling price of SKO has been kept significantly below its marginal cost of supply with a view to provide a cheap fuel for poorer sections of the population In 1990-91, the loss in the government revenue from this measure was estimated at Rs 2868 crores In comparison with increases in prices of other petroleum products, the basic ceiling price of SKO for domestic use was reduced in July 1991 The ratio of SKO to HSD prices went down from 0 66 in 1980 to 0.40 in 1992 The widening gap between the price of SKO and HSD has led to the misuse of SKO for adulteration with HSD for transport purposes. The supply of kerosene is rationed and routed through the public distribution system However, the scarcity caused by its diversion to other end-uses has forced the consumers to resort to black market purchases The All India Kerosene Dealers' Federation has confirmed that kerosene is not available to the target consumers at the Government approved prices and he has often to pay as high as Rs 12 per litre (as against the market price of Rs.2 66 to Rs.3 per litre) in urban areas Although the rationale for lower SKO prices is the Government's concern for the welfare of poorer households, for whom kerosene is a clean cooking and lighting fuel, the benefits have not accrued to the target population

Subsidy on LPG. LPG was subsidized for the domestic sector with a view to promote its use as a cooking fuel Given the convenience and cleanliness associated with its use the demand for LPG has risen at a rate which has far outstripped its supply leading to imports at the margin

Although LPG is called the rich man's fuel and has an established market, it continues to be sold at subsidized prices As per our estimates the concessions on LPG of about Rs 5 74 per kg (i e Rs 9 8-4 06) have resulted in a net revenue loss of Rs 1084 crores in 1990-91 On the consumption side, the differential pricing of LPG for domestic and non-domestic uses has led to its frequent misuse in commercial and industrial sectors The price differential between LPG and MS has led to the domestic LPG cylinder being used for running cars, although it is difficult to assess the magnitude of this problem Firstly, it is not justified to provide a subsidy on LPG with benefits accruing to the economically better off sections of the population In fact, until the recent petroleum price changes

in September 1992 the percentage subsidy on LPG was more than on SKO. Secondly, the subsidy has led to a distortion in consumption and therefore should not be allowed to continue.

Soft coke pricing. Soft coke is used for household cooking and for input in brick kilns. It is produced with the tradition 'Bhatta Method' which is an inefficient process leading to the formation of poorer quality soft coke. The production of soft coke has declined from 2 41 million tonnes in 1979-80 to 0 91 million tonnes in 1990-91 A lower availability would have led to substitution of kerosene and fuelwood in urban and semi-urban areas The reduction in output has been mainly on account of an incorrect pricing policy adopted by the Government Given the low pithead price of soft coke the producers are not getting adequate remuneration resulting in dwindling production and declining quality of soft coke The latter is also a consequence of the low prices and adoption of the traditional method of manufacturing soft coke Supply shortages coupled with poor quality fuel and inconvenience in its use have led the consumers substitute it with SKO (which is imported, involving foreign exchange) and/or fuelwood (with adverse environmental implications) for cooking purposes.

Differential pricing of naphtha and FO Under the prevailing price regime naphtha and FO for energy and non-energy purposes in the fertilizer industry are supplied at prices which are 55-60% lower compared to other uses The OPRC 1991, states that this has discouraged the substitution of natural gas as a feedstock for fertilizer manufacturing Given the thrust on natural gas development and use, especially as a feedstock in fertilizer and petrochemical industry, the concessional prices of naphtha and FO needs to be reviewed afresh

Subsidy on electricity for agriculture sector. The extent of electricity subsidy provided to the agriculture sector is as high as 85-90% in various states The benefits of the subsidies largely reaped by the farmers with above average land holdings, who are in a position to pay for much of their electricity consumption Low agriculture tariffs have encouraged the misuse of electricity and have severely affected the financial health of the SEBs It is therefore recommended that the subsidy to the agriculture sector should be reduced and the agriculture tariff revised to reflect the cost of generation and supply of electricity in all the SEBs

7. The Approach Summarised

As has been brought out in the preceding discussions, prices of different forms of energy in the country have not always reflected the efficiency considerations Even when prices have been fixed with specific social objectives in view, the same have rarely been achieved, in turn, this practice has resulted in obvious distortions in the demand pattern

In the coal sector, though prices have been fixed for different grades, based on Useful Heat Value (UHV), the wide range of UHV in each grade has encouraged supply of coal with UHV at the lowest of the ranges Besides, the correlation between prices of different grades of coal has not always been rational, resulting in consumers, particularly of the lower grades, paying a higher rate per unit of UHV compared to those using superior grade coals Coal is the most abundantly available primary form of energy in the country and encouragement of its use calls for a more rational pricing This can be achieved by narrowing the UHV range of each grade of coal to 500 kcal/kg and simultaneously pricing the goods in such a manner that the pithead price per unit of UHV by and large remains uniform with some premium for scarce and higher grades of coal Alternatively a single benchmark UHV may be taken and consumers asked to pay prices at a premium/discount with reference to such benchmark UHV Such an approach would also warrant a much greater initiative than at present for beneficiation of non-coking coal, particularly for consumers situated at distances over 500 kilometre from the pithead

To take care of domestic cooking energy demands, it is suggested that the supply of coal based products be increased significantly A TERI study has clearly brought out the economics of the use of coal products in the domestic sector by means of either the smokeless fuel (SF) technology, or the coal briquetting process In order to promote the use of these fuels in the domestic sector to substitute for scarce and more expensive energy fuels like kerosene and firewood, it is essential that research and development of better cookstoves based on these fuels is undertaken Also in order to ensure the right quality of SF/briquettes to the end-user it has been suggested that these fuels should not be transported over very long distances (say less than 300 kms) In order to ensure its widespread use, it would make better sense to transport the raw coal over long distances and produce the SF/briquettes closer to the point of consumption The large scale supply of these fuels can easily take care of those end-use demands in the urban areas which are presently being taken care of by firewood and kerosene

In the oil sector, similar irrationality can be found, particularly in the pricing of LPG and kerosene both of which are heavily subsidised LPG is largely consumed in urban domestic sector, particularly in those households

whose ability to pay the economic price clearly justifies a total removal of the subsidy In order to soften the impact, the removal of subsidy can be phased over the next 2/3 years As regards kerosene, one can argue for a certain amount of subsidy in view of the fact that the product is used for domestic cooking and lighting purposes by the relatively poorer people However, in the absence of appropriate administrative machinery, such subsidy has resulted in large scale mixing of kerosene with high speed diesel oil, thus depriving the targeted group the benefits that were to accrue from such subsidy In view of such diversions and resulting scarcity, retail prices of kerosene for consumers in the rural areas have been many times the official retail price A parity of the price between HSD and kerosene should lead to improved availability of kerosene and the market price for consumers in rural areas is likely to come down as a result

As regards natural gas pricing, a beginning has been made to reflect the opportunity cost in the consumer price which is set at a level higher than the producer price This process needs to be taken to its logical conclusion and the consumer prices should be so set that the need for sectoral quantitative allocation, as is the practice now, is totally eliminated A 2-yearly review of the administered prices of natural gas should be made to ensure optimal utilisation of this depletable form of energy in relation to the alternative forms that are available

The degree of irrationality is even larger in the electricity sector and this has resulted in heavy losses to the State Electricity Boards (SEB) In the case of the agriculture sector, the SEBs presently realise only 10-15% of their long run marginal cost of supply The immediate step towards rationalised tariff structure for the agriculture sector should be to move away from the 'flat rate' tariff to metered supply It is recommended that by the end of the Eighth plan the subsidies to the agriculture sector must be reduced to a maximum of 50% against the present level of 85-90% and by 2000 the SEBs should recover the LRMC of supply from this sector With Maharashtra State Electricity Board as an example, this would require that agriculture tariffs be raised to 65 paise/kWh by the end of the VIII plan, from the present level of average realisation of 15 paise/kWh The Union Government of India has recommended the SEBs and the State Governments to price electricity for agriculture sector at minimum 50 paise/kWh

Average revenue realised from the domestic sector in all the SEBs is also below the average cost of generation and supply and is only 40-50% of the long run marginal cost The inverted block tariff structure for the domestic sector needs to be appropriately designed so that while the consumers in the high consumption blocks subsidise the consumers in the lower consumption blocks, the domestic consumer category as a whole pays for the cost of supplying electricity to it The first step in this direction

should be to recover average cost of generation and supply and then gradually move towards recovering long run marginal cost

HT-industries account for nearly 42-50% of the load during the peak hours and therefore impose greater burden on the utilities to add new capacities The pricing of the SEBs should aim at ensuring efficient utilisation of the existing capacities by encouraging the HT-industries to shift load from peak to off-peak hours While designing time-of-day (TOD) tariffs what is most important is the right peak and off-peak price differential The experiments in many developed and developing countries with TOD tariffs have shown successful results with peak/off peak price differential of 2 5 1 - 2 1

Tariffs for commercial consumers and LT-industries should also gradually move towards recovering the long run marginal cost of generating and supplying electricity to them The share of street lighting though marginal in the overall electricity consumption is important because almost 25-30% of it falls during evening peak hours SEBs supply power for public lighting at 30-40% subsidised rate These subsidies should be gradually withdrawn along with a switch over from incandescents to fluorescents There is an even stronger case for switching over from High Pressure Mercury Vapour to High Pressure Sodium Vapour lamps Use of photocells for automatic switching-off of the lights should be encouraged

The main principles of energy pricing should be to ensure that the prices allow an adequate return to the producers and that they reflect the true economic costs The irrationalities in product pricing in different energy sub-sectors with reference to these principles have been brought out in the discussions above with appropriate recommendations The analysis clearly indicates that there is no deterministic correlation between prices and demand of products within the energy sub-sectors making it difficult to estimate the price-elasticities of demand because of continued physical shortages of products However even within this regime of physical shortages an integrated energy pricing approach is called for to ensure an optimal substitution of different forms of energy Absence of such an integrated approach has resulted in anomalous situations like coal prices at the consumer's end located at long distances from the pit head are being higher than substitutable oil products if we are to go by end-use efficiency of these products It is recommended that the country should move towards an integrated energy pricing structure based on long-run marginal cost of supplies in respect of non-tradeables and border prices in case of tradeables after taking into account inter-fuel substitution possibilities As pricing of different forms of energy is administered by different organisations such an approach would call for entrusting the work to an apex organisation with adequate expertise and authority to cover pricing in all energy sub-sectors This organisation should also be able to recommend pricing parameters to

State Electricity Boards on a normative basis A normative approach for SEBs is inescapable in view of the widely varying levels of efficiency - a syndrome from which SEBs must be brought out for imparting a minimum level of efficiency in electricity generation Since such an integrated approach would lead to much higher prices than at present in respect of certain forms of energy, the approach can be gradual with the object of reaching an optimal situation by the end of the 8th Five Year Plan period

To sum up, there is considerable scope for rationalising pricing in the different energy sub-sectors in an integrated manner as also for building adequate incentives in the pricing system to encourage optimal inter-fuel substitution and efficient production of different forms of energy

ANNEXURE 1

Price per unit of useful heat value for non-coking coal		
Grade	**Price Rs/tonne**	**Price per unit of Slack Coal Rs/10^6kcal**
Long flame coal produced in all states		
Grade A	427 00	87 7
Grade B	392 00	89 1-80 5
Grade C	346 00	88 9-78 4
Grade D	280 00	84 3-71 7
Other coal produced in all states		
Grade A	402 00	83 7
Grade B	367 00	84 6-76 5
Grade C	321 00	83 8-73 9
Grade D	255 00	78 3-66 6
Grade E	203 00	78 0-62 4
Grade F	163 00	87 5-62 5
Grade G	117 00	115 4-62 5
Coal produced in State of Andhra Pradesh (Singareni coal fields)		
Grade C	363 00	105 3-92 9
Grade D	320 00	109 0-92 7
Grade E	271 00	112 5-90 0
Grade F	205 00	129 6-92 6
Grade G	160 00	175 4-95 2

ANNEXURE 2

Trend in the base price, oil development cess, and royalty for indigenous crude oil (Rs/tonne)

Price effective	Base price	Oil development cess	Royalty	Total price
Onshore				
14 07 75	270 04	@	@	270 04
05 09 76	245 42	60 00	@	305 41
16 12 77	203 41	60 00	42 00	305 41
01 04 81	203 41	60 00	61 00	324 41
11 07 81	1021 00	100 00	61 00	1182 00
15 02 81	1021 00	300 00	61 00	1382 00
01 04 84	1021 00	300 00	192 00	1513 00
01 04 87	1021 00	600 00	314 00	1935 00
01 02 89	1021 00	900 00	314 00	2235 00
Offshore				
16 12 77	331 65	60 00	42 00	433 65
01 04 81	331 65	60 00	61 00	452 65
11 07 81	1021 00	100 00	192 00	1182 00
15 02 81	1021 00	300 00	61 00	1382 00
01 04 84	1021 00	300 00	61 00	1513 00
01 04 87	1021 00	600 00	192 00	1813 00
01 02 89	1021 00	600 00	192 00	1813 00

@ Included in the base price

Source Indian Petroleum and Natural Gas Statistics Ministry of Petroleum and Natural Gas Government of India 1990-91

ANNEXURE 2 (Continued)

Prices of imported and domestic crude oil (Rs/mt)

Year	Imported	Domestic		Effective Date
		On-shore	Off-shore	
1970-71	91			
1971-72	114			
1972-73	121			
1973-74	300			
1974-75	657	270 04	-	01 04 1975
1975-76	772	305 41	-	08 09 1976
1976-77	837	305 41	433 65	16 12 1976
1977-78	859	305 41	433 65	
1978-79	854	305 41	433 65	
1979-80	1357	305 41	433 65	
1980-81	2061	324 41	452 65	01 04 1981
1981-82	2442	324 41	452 65	01 04 1981
		1182 00	1182 00	11 07 1981
1982-83	2386	1382 00	1382 00	15 02 1983
1983-84	2218	1382 00	1382 00	
1984-85	2514	1513 00	1513 00	01 04 1984
1985-86	2435	1513 00	1513 00	
1986-87	1370	1813 00	1813 00	01 04 1987
1987-88	1684	1935 00	1813 00	
1988-89	1607	2235 00	1813 00	01 02 1989
1989-90	2098	2235 00	1813 00	
1990-91	2956	2235 00	1813 00	
'p				

'p' Provisional

Source Indian Petroleum and Natural Gas Statistics, Ministry of Petroleum and Natural Gas Government of India 1990-91

ANNEXURE 3

Rate of Return of Selected Indian Utilities

SEB	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91
APSEB	n a	n a	+02 51	+01 31	+00 18	+01 20
ASEB	-82 71	-183 12	-38 71	-38 77	-41 92	-41 30
BSEB	-19 00	+00 54	-02 52	-16 81	-17 40	-16 50
GEB	-00 17	+10 72	+01 90	+00 95	-12 64	-15 10
HSEB	-02 15	-90 79	-21 62	-05 83	-15 32	-22 20
HPSEB	-09 66	-42 54	-15 17	-17 20	-12 70	-16 80
KEB	-06 80	-17 22	-21 65	-09 28	-14 6	-16 10
KSEB	+00 10	-01 62	-16 52	-04 39	-02 76	-08 20
MPEB	+04 34	+05 94	+02 98	-00 59	+00 61	+02 60
MSEB	+02 82	+02 90	+02 87	+01 41	+00 45	
OSEB	-02 35	-00 86	-09 73	-04 93	+03 21	+00 60
PSEB	-00 48	-01 26	-00 31	-03 57	-02 48	n a
RSEB	-05 04	-02 47	-06 04	-04 80	-07 78	-11 7
UPSEB	-06 04	+02 89	+01 82	+00 04	+01 11	n a
WBSEB	-07 85	-02 34	-08 20	-08 95	-10 24	n a

Source: GOI Planning Commission Power and Energy Division Annual Report on the Working of State Electricity Boards and Electricity Departments

ANNEXURE 4

Growth rate of electricity tariffs during the period 1984/85 to 1989/90

SEB	Dom *	Comm *	Agri *	Small Indy*	Medium Indy*	Large Indy*	Total
Andhra Pradesh	5.23	6.55	0.00	10.07	11.78	11.56	6.14
Assam	1.61	7.54	10.76	6.75	10.52	13.11	11.93
Bihar	0.00	2.84	0.00	6.58	6.68	7.44	5.36
Gujarat	2.10	11.44	-12.03	9.62	6.93	11.90	3.05
Harayana	5.57	7.55	5.42	22.91	17.40	19.47	5.43
Himachal Pradesh	0.30	3.97	0.00	11.27	16.94	16.83	2.96
J&K	-1.24	8.45	0.00	18.41	15.17	17.66	9.53
Karnataka	7.95	11.23	8.45	17.32	15.70	18.16	6.32
Kerala	0.00	9.46	0.00	16.86	21.04	11.06	8.88
Madhya Pradesh	1.05	3.79	0.00	10.71	8.52	13.28	4.70
Maharashtra	3.25	10.24	-7.79	12.23	13.93	10.68	7.58
Orissa	2.34	12.45	14.15	10.64	9.84	13.43	6.81
Punjab	3.02	6.96	-0.04	11.61	14.24	14.15	3.76
Rajasthan	5.46	11.35	8.45	15.72	13.89	13.63	6.45
Tamil Nadu	0.60	7.90	-7.79	10.46	13.58	13.96	4.19
Uttar Pradesh	4.92	3.36	0.00	16.44	14.94	12.82	6.51
West Bengal	0.72	8.07	0.00	2.77	0.00	12.45	5.91
Goa	5.39	6.83	8.16	7.57	8.92	12.44	n a
Mizoram	8.75	7.96	9.46	27.12	27.68	24.20	n a
Nagaland	9.34	6.21	0.00	0.95	10.03	10.03	n a
Sikkim	5.14	9.86	9.86	9.86	6.43	8.33	n a
DESU	0.00	12.72	-5.29	15.47	15.47	13.47	n a

* Domestic - 30 kWh/month
Commercial - 200 kWh/month
Agriculture - 5 MP, 10% Load factor, i.e. 272 kWh/month
Small Indy - 5 MP, , 10% load factor, i.e. 272 kWh/month
Medium Indy - 50 kW, 30% load factor, i.e. 10950 kWh/month
Large Indy - 1000 kW, 50% load factor, i.e. 365000 kWh/month

Source: Average electricity rates and duties in India, April 1990. Central Electricity Authority, Government of India

ANNEXURE 5

Level of demand satisfaction in the coal sector during the last three years

	1990-91			1989-90			1988-89		
	Demand	Offtake	Demand satisfaction (%)	Demand	Offtake	Demand satisfaction (%)	Demand	Offtake	Demand satisfaction (%)
Power	108 05	106 32	98 40	100 40	100 27	99 87	90 81	89 29	98 33
Steel	22 60	20 53	90 84	22 80	19 80	86 84	22 50	20 32	90 31
Total	191 78	182 94	95 39	185 72	173 56	93 45	173 50	165 02	95 22

Source Annual Performance Report 1990 91 Coal India Limited, Calcutta

ANNEXURE 6

Methodology for calculation of the EP, MP and BP of coal

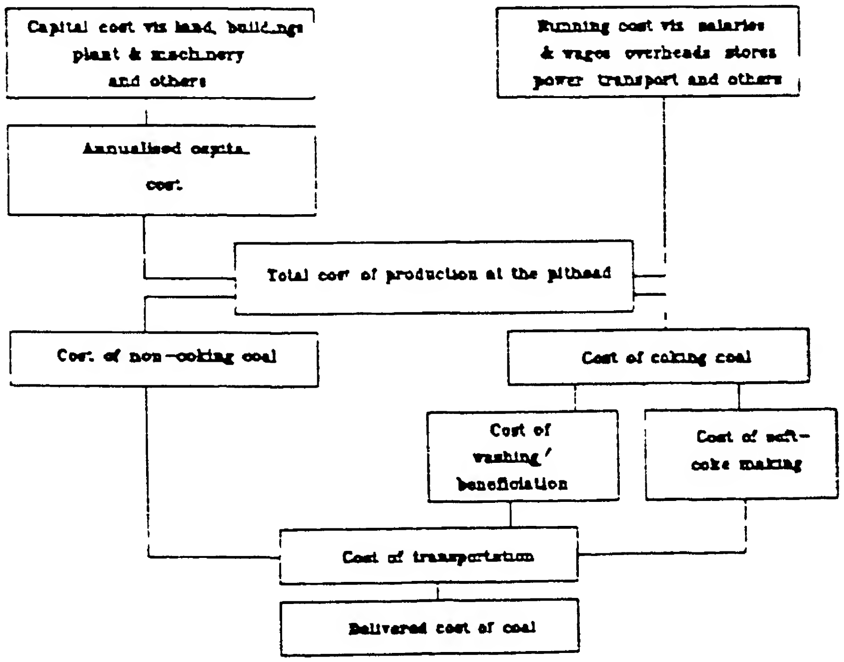
Economic price. The economic price of coal was estimated on the basis of its average incremental cost (AIC) of production, that is, the average cost of producing an additional unit of coal in the long run

The cost of extracting coal is related to the geo-mining characteristics (such as depth of the mine, thickness of the coal seam, inclination, etc.) and has no relationship with the quality of coal being mined Thus, in the present study, the cost of production has been calculated for two broad categories of mines, that is, opencast (OC) and underground (UG) representing technologies suitable for different geological parameters The base year of analysis was taken as 1990-91 Both capital as well as operating costs were taken into account for computing the AIC of producing coal from UG and OC mines Furthermore, the cost of washing of coking coal and manufacture of soft coke (using the new special smokeless fuel (SSF) technology), were also computed

The cost of transportation constitutes a significant portion of the delivered price, especially in case of non coking coal The real resource or economic cost of transporting coal from the mine head to its point of consumption was also included in the economic price The economic price was estimated for varying slabs of distance over which coal is transported

The following flow chart depicts the economic price build up for coal

Figure 14: Effluent price build-up of coal



Market price· The government administers the pithead price of coal while leaving the price paid by the consumers largely unregulated Thus, to arrive at the delivered market price of coals and soft coke are added the components of royalty, cesses, excise tax, sales tax and the transportation costs to the pithead price

Border price Presently, India is importing good quality coking coal from Australia for consumption in the steel plants The imported coking coal being low in ash content, is used for blending with the indigenous coking coals having higher ash contents Although we are not importing superior grade non coking coal its border price has been estimated when imported from Australia.

Thus, in case of both superior coking and non coking coals, the f o b price is taken as the starting point The c i f price (inclusive of a 40% foreign exchange petroleum) is calculated by adding the freight charges from Australia to India by sea

To the c i f price are added the port handling charges and cost of transportation to arrive at the delivered price of coking and steam grade coals

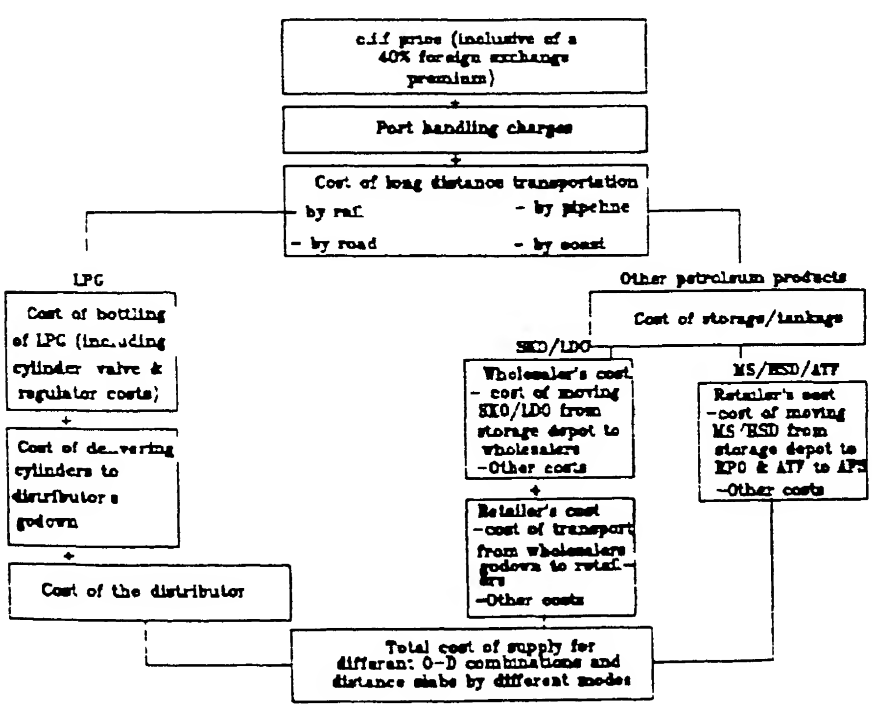
ANNEXURE 7

Methodology for calculation of the EP, MP and BP of petroleum products

Economic price / Border price All petroleum are traded/tradeable commodities and an increasing demand for these products, given a limited domestic availability, has necessitated their import at the margin Hence, in the present analysis the economic price of these products was based on their border price All prices and costs were worked out for the year 1990-91

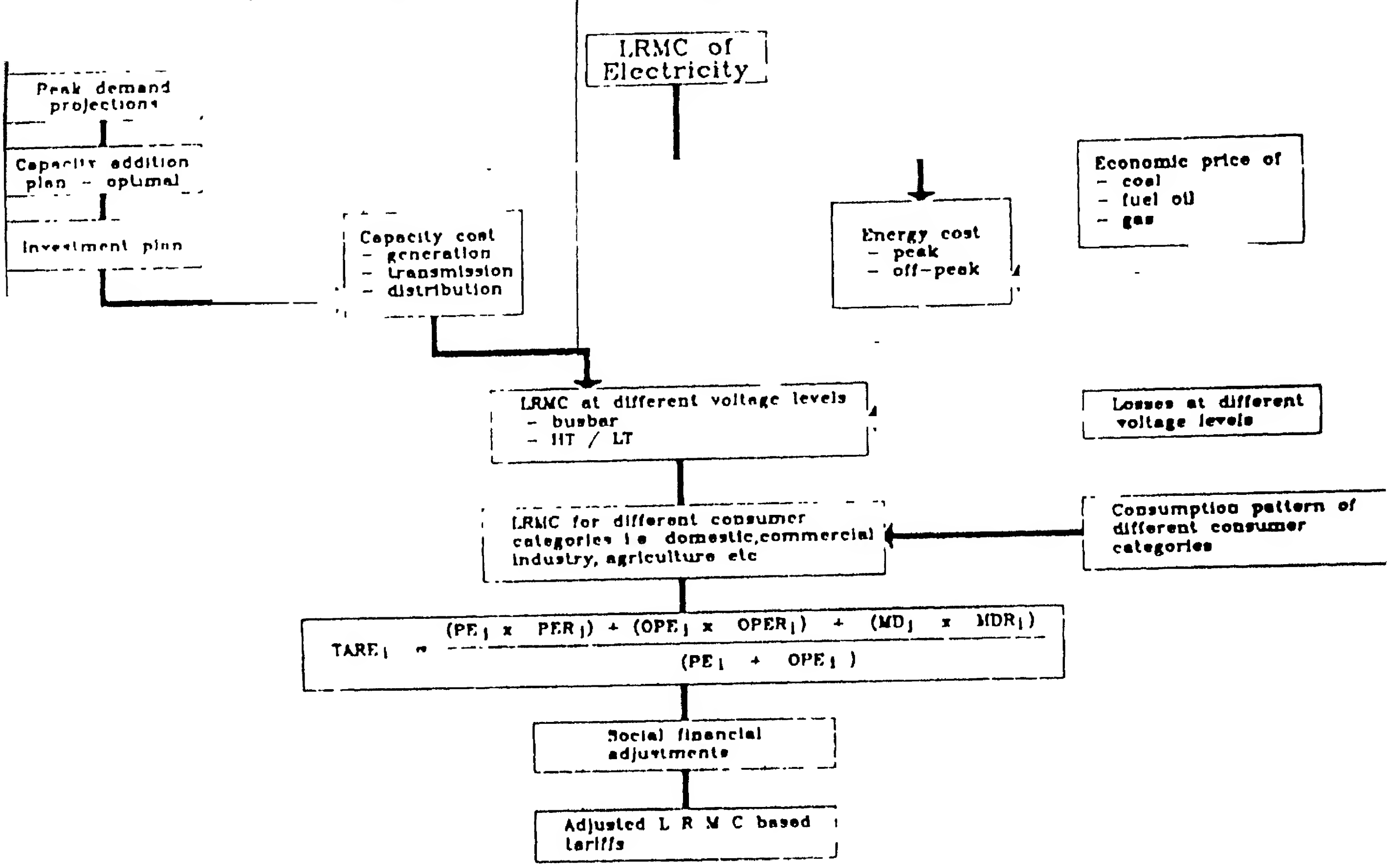
The c i f price inclusive of a foreign exchange premium (to reflect the scarcity of foreign exchange reserves) was considered as the starting point for computing the economic cost of supplying the individual product To the c i.f price were added the costs of handling imports at ports, transportation, storage/tankage facilities at depots, bottling of LPG and marketing and distribution by oil refining companies or intermediaries to arrive at the economic price of the fuel The price was computed for different slabs of distance over which the product is transported The following flow diagram (Fig 15) shows the price build up which has been adopted for estimating the economic price The economic price calculated by distance slabs for different products are presented in the table below.

Figure 15: Efficient price build-up of petroleum products



Market price: The market price of petroleum products refers to the retail selling price. These prices, as charged in major towns/cities of India were taken from the Petroleum and Natural Gas statistics, 1990-91, Government of India

Flowchart for calculating LRMC based tariffs



ANNEXURE 9

Economic price of natural gas

The Average Incremental Cost (AIC) is estimated by discounting all incremental cost that will be incurred in future to provide and maintain the estimated amount of gas over a specified period of time and dividing it by the discounted volume of incremental output over this time. The stream of expenditure on capital and operations is to correspond to a certain flow of production The AIC is calculated using the following formula

$$\frac{\sum \left[I_t + (R_t - R_c) \right] / (1+i)^t}{\sum (Q_t - Q_c) / (1+i)^t}$$

where,

I_t = capital cost in year 't'

R_t = operating and maintenance costs in year 't'

Q_t = natural gas production in year 't' associated with the investment

i = social rate of discount

T = gestation period for the development project and the production life

The AIC has been estimated for the (i) production, (ii) transportation and (iii) distribution from South Bassein gas fields is calculated and the transmission cost are estimated along the HBJ pipeline The cost of distribution of gas is estimated over a 25 kms distance from the mother station

ANNEXURE 10

Domestic sector analysis

Fuel	Price (Rs tonne or kWh or 000m3)		Price (Rs/10000 kcals)		Efficiency matrix		End use prices			
	EP	MP	EP	MP	Lighting (kcals/'000 lhr)	Cooking & W heating (Ukcals/kcal)	EP	MP	EP	MP
							Lighting (Rs 000 lhr)		Cooking & W Heating (Rs /10000 kcals)	
Soft coke	938.00	467.29	1.86	0.93		0.25	0.00	0.00	7.50	3.74
SKO	6945.00	2891.30	6.31	2.68	2.88	0.45	1.82	0.76	14.03	6.84
LPG	9778.00	4057.04	8.32	3.45		0.65	0.00	0.00	12.80	6.31
Electricity#	1.49	0.71	17.30	8.26	0.17	0.64	0.29	0.14	27.07	12.90
Electricity*	1.49	0.71	17.30	8.26	0.03	0.64	0.05	0.02	27.07	12.90

Note lhr lumen hours
U Kcals - Useful Kilocalories
\# Electricity use in incandescents
* Electricity use in fluorescents

Domestic sector consumption analysis

Fuel	Unit	Consumption matrix (1987-88)		Realisations (Rs Million)				Fuel subsidy (Rs million)
		Lighting	Cooking & W Heating	Lighting		Cooking W Heating		
				EP	MP	EP	MP	
Soft coke	mt		0.56			525.28	261.68	263.60
SKO	mt	1.58	5.50	10957.80	4561.88	38180.30	15895.00	28681.21
LPG	m'		1.89			18519.53	7684.04	10835.49
Electricity	mkWh	26255		39124.42	18643.2			20481.24
Total				50082.21	23205.06	57225.11	23840.72	60261.54

Note Realisation based on economic prices refer to desired (or required) levels of realisation

Industrial and commercial sector analysis

Fuel	Price (Rs tonne or kWh or 000m3)		Price (Rs/10000 kcals)		Efficiency matrix		End use prices			
	EP	MP	EP	MP	Process heating (Ukcals/kcal	Lighting (kcals 000 lhr)	EP	MP	EP	MP
							Process heating (kcals '000 lhr)		Lighting (Rs/000 lhr)	
Non coking coal	541.13	682.46	1.20	1.52	0.55		2.19	2.76		
Coking coal	802.62	1166.55	1.27	1.87						
Fuel oil	2839.00	3481.28	2.73	3.35	0.75		3.64	4.46		
Natural gas	2159.50	2250.00	2.47	2.57	0.80		3.09	3.22		
Electricity com*	1.63	1.47	18.95	17.09		0.17			0.32	0.29
Electricity com°	1.63	1.47	18.95	17.09		0.03			0.06	0.25
Electricity LT*	1.36	1.14	15.81	13.26		0.17			0.27	0.23
Electricity LT°	1.36	1.14	15.81	13.26		0.03			0.05	0.04
Electricity HT*	0.97	1.58	11.28	18.37		0.17			0.19	0.31
Electricity HT°	0.97	1.58	11.28	18.37		0.03			0.03	0.06

* Electricity use in incandescents ° Electricity use in fluorescents

Industrial and commercial sector consumption analysis

Fuel	Unit	Consumption matrix				
		Process heating	Ore reduction	LT	HT	Commercial
Non coking	mt	171.46				
Coking coal	mt		30.87			
Fuel oil	mt	5.975				
Natural gas	mcm	1178				
Electricity com	mkWh					8807
Electricity LT	mkWh			15675		
Electricity HT	mkWh				68635	

Industrial and commercial sector - consumption analysis (contd.)

Fuel	Realisation (Rs million)										Fuel subsidy (Rs million)
	Process heating		Ore reduction		LT		HT		Commercial		
	EP	MP	EP	MP	EP	MP	EP	MP	EP	MP	
Non coking	92782 14	117014 60									-24232 4
Coking coal			24776 7	36011 24							-11234 5
Fuel oil	16963 02	20800 36									-3837 3
Natural gas	2543 89	2650 50									-106 6
Electricity comm.									14355 40	12946 3	1409 1
Electricity HT					21590 00	18097 00					3492 5
Electricity LT							66769 9	108759 3			-41989 4
Total	112289 1	140465 5	24776 7	36011 24	21590 00	18097 00	66769 9	108759 3	14355 40	12946 3	-76497 8

Note: Realisations based on economic prices refer to desired (or required) levels of realisation.
A negative subsidy implies a tax on the fuel.

Transport sector analysis

Fuel	Price (Rs tonne or kWh)		Price (Rs /10000 kcal)		Efficiency matrix		End use prices			
	EP	EP	EP	MP	Freight (kcal/TKM)	Passenger (kcal/PKM)	EP	MP	EP	MP
							Rs /000 TKMS		Rs /000 PKMS	
Non coking coal	541 13	682 46	1 20	1 52	913 50	315 00	109 85	138 54	37 88	47 77
Motor spirit	6008 00	14032 32	5 39	12 59		528 37			284 70	664 96
HSD-rail	6182 00	4925 79	5 72	4 56	76 68	50 76	43 89	34 97	29 06	23 15
HSD-road	9182	4925 79	5 72	4 56	452 35	62 83	258 93	206 31	35 96	28 66
Electricity-rail	0 97	1 29	11 28	18 37	18 92	15 82	21 34	34 76	17 84	29 06

Transport sector - consumption analysis

Fuel	Unit	Consumption	Realisation (Rs million		Fuel subsidy (Rs million)
			EP	MP	
Non coking coal	mt	5 24	2835 52	3576 09	-740 60
Motor spirit Road	mt	3 545	21298 36	49744 57	-28446 20
HSD-Rail	mt	1 45	8982 45	7157 17	1825 27
HSD-Road	mt	17 37	107356 60	85541 25	21815 36
Electricity Rail	mkWh	3688 00	3577 36	4757 52	-1180 16
Total			144050 20	150776 60	-6726 30

Note Realisation based on economic prices refer to desired (or required) levels of realisation
A negative subsidy implies a tax on the fuel

Agricultural sector analysis

Fuel	Price		Price		Efficiency Kcals/m3	End use price	
	EP	MP	EP	MP		EP	MP
	Rs/tonne (or kWh)		Rs 10000 kcal			Rs '000 m³	
HSD	6182 00	4125 80	5 72	4 56	349 65	200 14	159 47
Electricity	1.31	0 15	15 23	1 74	87 80	133 74	15.31

Agricultural sector consumption analysis

Fuel	Unit	Consumption	Realisation		Fuel subsidy (Rs million
			EP	MP	
HSD	mt	0 329	2033 88	1620 56	413 29
Electricity	mkWh	45971	60222 01	6895 65	53326 36
Total					

Note Realisation based on economic prices refers to desired (or required levels of realisation)

Renewable Energy Policy and Planning

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Training Programme
on Energy Planning
for South Asian Countries

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AN OVERVIEW ON INDIA'S PROGRAMME ON RENEWABLE ENERGY DEVELOPMENT AND UTILIZATION

BY

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1.0 INTRODUCTION

1.1 Development and utilization of non-conventional energy sources has been accorded priority in India for many years. The recent elevation of the erstwhile Department of Non-conventional Energy Sources to a full-fledged ministry symbolizes the Government's commitment to providing further impetus and thrust to this sector. The establishment of a separate ministry together with liberalized economic policies have created new opportunities to promote increased commercialization of technologies that have already matured and to mobilize support for intensifying research and development, and demonstration activities in promising areas. Based on the experience of the past 10-15 years, the new ministry has re-oriented its programmes with particular emphasis on market development and greater role for the private sector and non-Governmental organizations (NGOs).

2.0 India faces many problems and challenges with regard to development and management of its energy sector, because energy demand has been increasing at an alarming rate, and physical and financial resources are limited.

2.1 Although vigorous efforts are underway to create additional power generation capacity and render the energy system more efficient, there are growing concerns that the vast majority of people in rural areas will continue to face energy crunch unless ways and means are found to harness locally available energy sources. In addition, environmental issues and the alarming long-term outlook for conventional energy sources are compelling enough reasons to turn attention to renewable sources of energy. It is against this backdrop that India has embarked on a very major programme [illegible] innovative policies, [illegible] institutional arrangements, [illegible] development, information dissemination and industrial production.

3.0 During the past 15 years, the renewable energy programmes in India have evolved in three distinctive stages. In the first stage, from about the late '70s to the early '80s, the thrust of the national effort in this field was directed towards capacity building and R & D, largely in national laboratories and educational institutions. The second stage, from early '80s to the end of the decade, witnessed a major expansion with accent on large-scale demonstration and subsidy driven extension activities. These programmes created awareness and also generated field experience. The extension programmes, particularly in the

areas of biogas and improved woodstoves (chulhas), generated a vast network of institutions and non-governmental organizations, right down to the level of self-employed workers and establishments at the grassroot level. In the third and current stage, extending from the beginning [illegible] this decade, the emphasis has been more on application of mature technologies for power generation, based on [illegible] small hydro, bagasse cogeneration and other [illegible] as well as for industrial applications of solar [illegible] forms of energy.

4.0 INSTITUTIONAL FRAMEWORK

4.1 The Ministry of Non-conventional Energy Sources (MNES) is the administrative ministry for policies and programmes in this area. A high-powered commission called the Commission for Additional Sources of Energy, vested with full executive and financial powers of government, provides policy guidance and approves plans and programmes prepared by various divisions of the ministry. The ministry itself is organized into several divisions dealing with a set of technologies and applications. The ministry's plans and programmes are incorporated into the Five Year Plans by the Planning Commission after finalizing the allocations for the ministry.

4.2 The extension programmes of the ministry are largely implemented through State Nodal Agencies. All major States

have set up energy agencies exclusively for non-conventional energy programmes. These agencies, in turn, mobilize participation of local institutions, non-Governmental organizations (NGOs) and village-level organizations for implementation of programmes. R&D programmes are sponsored by the ministry mainly in educational institutions, national laboratories and to some extent, in industries, both public and private. The ministry has set up a Solar Energy Centre for training and manpower development testing and certification of renewable energy devices.

[illegible] For market development and financing of renewable energy projects a separate financing institution called the Indian Renewable Energy Development Agency (IREDA) has been set up as a public sector undertaking. Grants and soft loans from international agencies for market development are beginning to be entrusted to IREDA. A number of industries in solar, wind and biomass areas have started to commercialize renewable energy systems on their own.

5.0 PROGRESS OF RENEWABLE ENERGY DEVELOPMENT AND APPLICATIONS IN INDIA

5.1 India has evolved a wide-ranging programme covering research and development, demonstration, extension and commercialization of renewable energy systems. The programmes cover solar, wind, biomass, small hydro, cogeneration, urban and industrial waste utilization,

alternate fuels, hydrogen, fuel cells, ocean, tidal and geothermal energy.

5.2 A noteworthy feature of India's thrust in renewables is that there has been a steady increase in Government's financial allocations over the successive five year plan periods, although the total allocation is still a small fraction (less than 1%) of the allocation [illegible] the conventional energy sector. From an allocation of Rs [illegible] million in the Sixth Plan (1980-85), it increased to [illegible] million during the Seventh Plan (1985-90). The Eighth Plan allocation (1992-97) for the Ministry, because of resource constraints, is Rs.8500 million, which is somewhat [illegible]. However, efforts are underway to mobilize additional resources from both internal and external sources.

6.0 <u>DIFFUSION OF BIOGAS AND IMPROVED WOOD STOVES (CHULHAS)</u>

6.1 The launching of national programmes in biogas and improved wood stoves (chulhas) through what are called 'extension mechanisms' somewhat on the lines of agricultural extensions resulted in diffusion of these technologies and through local initiatives on a fairly large scale. Approximately, 1.7 million biogas plants and 15 million improved wood stoves have so far materialized. These two programmes in India have demonstrated the rather complex process of 'going to scale'.

6.2 The programme design has been continuously evolving for several years. It has paid attention to all major aspects - incentives, village-level motivation, training, turn-key installation, access to bank credit (through National Bank for Agriculture and Rural Development - NABARD), subsidies, repair and service mechanisms etc. Both programmes have faced numerous technical, operational, financial and social acceptance problems, but nevertheless, the continuous improvements have brought greater technical reliability and wider user acceptance. The large subsidy that was introduced, initially, has decreased substantially in real terms and there are reasonable indications that the programme can be sustained on the basis of incentives and financing arrangements, without resorting to direct subsidies. These two programmes in India exemplify the kind of approach that, if suitably adopted for local situations, could prove successful in extending relevant technologies to rural areas.

6.3 The size of family-type biogas plants has shifted from the larger sizes of 4 cu.m plant to 2 cu.m. plants. Apart from cost considerations, the availability of sufficient number of cattle for feeding the plant seems to be one of the principal factors. User preference in some States is for the fixed dome type plants (Indian adaptation of a Chinese

design - called the Deenabandhu Model). The programme has been making steady and good progress, at the rate of 200,000 plants per year. Independent evaluations have showed that non-operating plants range from 10-40%, depending on local factors. On an average, operational status has been around 75-80%, which is considered good. Similarly, in the case of chulhas, a multi-model approach has been [illegible], with incentives, turn-key contracts and [illegible] groups. It however continues to enjoy subsidy to a large extent, which in a way is justifiable on the [illegible] that the chulha, apart from more efficient use [illegible] contributes to removal of drudgery, improved [illegible] and environment, and thereby benefiting the [illegible].

7.0 SOLAR TECHNOLOGIES

7.1 Considerable progress has been achieved in the introduction of solar water heating systems for use in industrial and commercial establishments, such as for dairies, hotels and hospitals. So far, about a quarter million square meters of solar collectors have been installed. Production of solar water heating systems is being undertaken in the country by over 70 firms and the overall quality and performance is comparable to what is available elsewhere in the world. For ensuring quality, the Bureau of Indian Standards have formulated standards along the lines of other international standards. Testing and

certification facilities for solar collectors have been established at the SEC and at several regional institutions. Till recently, a subsidy ranging from 33-50 per cent was being given for solar water heating systems. This subsidy has been phased out and in its place, financing arrangements involving soft loans have been introduced under IREDA. In addition, incentives are also available. In spite of subsidy, domestic solar water heating systems have not been very popular. Only about 5000 systems have been installed. Tax benefits could create favourable response from users and therefore, efforts are underway to provide tax benefits.

7.2 Solar passive concepts have been introduced for green houses, agricultural drying and for heating dwellings in cold regions of India. Experimental passive buildings have been built in different climatic regions for testing and evaluation purposes. Efforts are underway to intensify and expand the applications of solar architecture in urban and rural areas.

7.3 Box-type solar cookers developed in India are gaining popularity, largely due to interest shown by women's groups and voluntary organizations. About a quarter million solar cookers have been sold so far and several small scale industries are fabricating solar cookers in the country. The Government provides a subsidy on solar cookers to the extent of about 25% and in addition, some State Governments also

provide 20-25% of subsidy on their own. The fuel saving potential of solar cookers makes it an attractive device, considering the estimated pay-back period of less than 2 years.

7.4 Several other applications of solar thermal devices such as solar stills, solar grain driers, timber kilns, solar process steam technologies etc. have been developed and demonstrated. These technologies have reached a stage of technical readiness, but commercialization will depend on industries setting up marketing outlets and on the availability of credit facilities.

7.5 India has made significant strides in the area of solar photovoltaics. Sustained efforts by industry with the support from Government through a large R&D-cum-demonstration programme, have resulted in the development of a variety of photovoltaic systems. A self-reliant industrial base has evolved covering materials, solar cells, modules and systems on a fairly large-scale. A variety of photovoltaic systems for telecommunications, lighting, village power plants, vaccine refrigeration, pumping systems etc. have been developed and more than 50,000 PV systems have been deployed. In terms of sheer numbers, this constitutes one of the largest deployment of PV systems in any developing country.

7.6 India's photovoltaic industry comprises of both public and private sector units. It produced in 1992-93, about 2.3 MW of PV modules, comprising about 1.07 MW by Central Electronics Ltd., 0.5 MW by Bharat Heavy Electricals Ltd., 0.2 MW by Rajasthan Electronics and Instruments Ltd., 0.2 MW by Tata BP Solar, 0.16 MW by Renewable Energy Systems and 0.03 MW by Udhaya Semiconductors, and the total turn-over of the industry is of the order of Rs.850 million.

7.7 The principal barrier for wider PV use is its high initial cost. Despite its high cost, photovoltaic systems have been found to be ideally suited for small power applications in unelectrified and remote locations. During the current year, a market development project has been initiated with support from the World Bank. The project will assess market conditions, evolve marketing strategies, provide the necessary impetus to market development through manufacturers and market intermediaries, setting up outlets, service arrangements and financing mechanisms on soft lending basis. A target of 5-10 MW of PV deployment over a five year period has been envisaged under this project.

7.8 Besides this, the Government of India have initiated a project on Solar Photovoltaic Pumping for Irrigation, involving a strategy that seeks to promote sale of PV pumps of 500-900 W capacity to farmers at their ultimate commercial price by underwriting the difference in present

and future cost as subsidy, given directly to manufacturer.

7.9 While efforts of this kind for market development have started, there has been a major development in the commercialization of photovoltaic systems for telecommunications. The Department of Telecommunications in India have adopted PV power units of 70 watts capacity for their rural telephone systems. During the last two years, nearly 50,000 such systems have been procured on the basis of open tender and installations have started. The total requirement has been assessed to be in excess of 100,000 units over the next couple of years. Other sectors such as railways, defence have also started utilizing photovoltaic systems by commercial procurement for their specialized requirements.

8.0 WIND POWER GENERATION - A MAJOR THRUST AREA

8.1 Substantial progress in wind power development has been achieved in India since the mid-eighties. The demonstration wind farms sponsored by the Ministry, and the identification of windy locations through wind surveys have spurred wide-spread interest on the part of industry, utilities and private sector developers. The wind power potential has been estimated at 20,000 MW. About 75 MW capacity is operational and another 40 MW is in various stages of implementation. This progress has been possible due to the progressive policies of the government for inducting technology,

introducing attractive incentives, arranging for wheeling, banking and buy-back of power by utilities. Licence production of 250 KW wind electric generators have now been started by four Indian firms, three in the private sector and one in the public sector.

8.2 A project for wind farm development with World Bank assistance has been initiated. The principal aim of this project is to commercialize wind farms through policy and financial instruments. For this purpose, soft loan arrangements have been introduced under IREDA. Profit making companies can borrow funds from IREDA for wind farms, in addition to claiming 100% depreciation in the first year itself. Tax holiday and exemption from payment of sales-tax, excise duty are also applicable. Project financing and procurement follow World Bank norms. A national testing and certification facility is being established. A wind energy centre is also being established at the Indian Institute of Technology, Madras.

9.0 SMALL HYDRO POWER

9.1 MNES is responsible for promoting small hydro power projects of upto 3 MW capacity. Preliminary estimates made earlier by the Central Electricity Authority indicate a potential of about 5000-6000 MW through small hydro projects. So far, 93 MW of capacity in this category has already been established and additional projects of 150 MWs are under various stages of implementation. Nearly all the

equipment of small hydro power is produced in the country. As many as 10 firms are engaged in production activities. The industry has introduced several incentives for promotion of small hydro power, particularly to attract private sector involvement. A capital subsidy of upto 25% on civil works and equipment is given for grid-connected projects, and upto 50% subsidy for non-grid connected projects. A separate project for canal-based small hydro projects has been initiated with World Bank funding support with a view to bring about accelerated commercialization with soft-lending replacing subsidies. All provisions with regard to wheeling, banking and buy-back of power and 100% depreciation are also applicable to small hydro projects. A new project for developing small hydro resources of hilly regions of India is being initiated with possible support from UNDP under Global Environment Facility funding.

10.0 BIOMASS TECHNOLOGIES

10.1 In the area of biomass, MNES have sponsored R&D projects for screening and cultivation of fast growing species of plants, and established several biomass research centers that also serve as nursery centers. Several biomass demonstration projects in different climatic regions of India have been undertaken.

10.1 Notable progress has been achieved in biomass gasification technologies. Biomass gasifiers in the range of

5-500 KW has been developed and tested under field conditions. The aggregate capacity of biomass gasification units installed so far, is of the order of 5 MW. A 100 KW biomass gasifier has been installed in Andaman Islands in a timber unit. A variety of feed stocks based on agricultural residues have been identified for use in gasification units. The Indian R&D establishments have made noteworthy progress with regard to optimization of biomass gasifiers and improving its operational reliability and gas quality. The gasifier systems incorporate more effective scrubbers and tar removal systems than those used in earlier designs. Work has also been carried out on modification of engines to work on gasified biomass with and without diesel support. Direct combustion of biomass in a large number of fluidized bed boilers has also been studied. A 10 MW rice straw-based demonstration project has been completed in the State of Punjab and is undergoing performance tests.

11.0 BAGASSE COGENERATION

11.1 Studies on bagasse cogeneration have identified a potential of 4000-5000 MW from 400 sugar plants in the country. A systematic programme to promote bagasse cogeneration with a package of incentives and financing arrangements has been launched. Residues from industrial plants as well as municipal wastes have also been pursued as a potential source of energy, apart from environmental

benefits in the sugar industry, for treating distillery effluents. The programmes spearheaded by the Ministry has reached full commercialization of bio-methanation of distillery effluents, with IREDA providing near-commercial loans for such projects.

12.0 ENERGY FROM URBAN AND INDUSTRIAL WASTES

12.1 A comprehensive programme for recovering energy from urban and industrial wastes has been formulated for possible funding under the UNDP/GEF/World Bank Technical Assistance Scheme. The programme seeks to introduce high rate bio-methanation technology for treating industrial effluents in a variety of industries like leather, paper, chemicals etc.

13.0 PROMISING TECHNOLOGIES

13.1 Turning to longer-term technologies, multi-institutional, coordinated research and development programmes have been pursued in the areas of hydrogen, fuel cells, alternate fuels, battery powered vehicles and chemical sources of energy. In the area of hydrogen, the Banaras Hindu University, Varanasi has developed hydrogen storage materials (metal hydrides) that hold great promise. Storage materials developed in India have been used to run a motorcycle on hydrogen. A range of 25 kms. has already been achieved with a single charge of hydride material (about 10 kg. containers), and is poised to achieve 50 kms. per charge in the near future.

13.2 Work on fuel cells has already resulted in the development of a 10 KW phosphoric acid fuel cell module. A 200 KW fuel cell plant is planned for testing under conditions of use in our Industry. Research has also been successfully carried out on methane reforrers for fuel cell use. Several demonstration projects have been undertaken on alcohols, both methanol and ethanol blended with petrol. A fleet of vehicles have been tested over a period of time extending to several years. MNES has pursued for some time, the development and testing of battery-powered vehicles for intra-city use. A demonstration programme, [illegible] over 10[illegible] vehicles has been undertaken Currently [illegible] battery operated mini-bus commuter service is being operated between two office complexes in Delhi and the performance of the vehicles is being monitored.

13.[illegible] A coordinated research programme on Chemical Routes for Trapping Solar Energy (CHEMTRAPSE), involving basic research work has been sponsored by MNES. The research activities covered are photo-electrochemical conversion, photo-catalysis and bio-memetism. Efforts in these areas have contributed to generation of capabilities in the fields that have long-term prospects.

14.0 NEW ORIENTATION OF RENEWABLE ENERGY PROGRAMMES

14.1 With the establishment of a separate Ministry of Non-conventional Energy Sources, and the current accent on

market orientation, programmes which hitherto, were undertaken on technology lines have now been reorganized into four distinct groups of activities, with a view to place greater emphasis on applications and commercialization. These are:

a. Urban and industrial energy systems;

b. Rural energy systems;

c. Grid-interfaced power generation systems.

d. New technologies.

- Urban and industrial energy systems cover solar heating and cooling systems, process steam generation, solar cookers, solar architecture, municipal and industrial wastes and energy conservation;
- Rural energy systems cover biogas, improved woodstoves, photovoltaic lighting, pumping and other rural applications, solar air-heating for grain drying, greenhouses.
- Grid-interfaced power generation systems cover wind power, solar thermal power, cogeneration, small hydro power and solar photovoltaic power plants.
- New technology area covers hydrogen, fuel cells and chemical sources of energy, ocean energy, tidal, energy, alternate fuels and geothermal energy.

14.2 Based on this reorientation of the ministry's activities, a plan has been evolved, which seeks to enlarge the activities with a four-fold increase in targets with a

view to accelerating the pace of renewable energy development and utilization.

15.0 COMMERCIALIZATION OF RENEWABLE ENERGY TECHNOLOGIES

15.1 Current policies seek to encourage industries and market intermediaries to establish marketing outlets and to provide quality products and after-sales service to users directly. In order to accelerate commercialization, a package of incentives have been introduced, the main features of which are as follows:

* Liberalized licencing policy to facilitate setting up of industries or foreign collaboration. Foreign investment is encouraged and automatic clearance procedures have been established.
* Customs duty on a number of imported items have been reduced. Further rationalization of duties is likely in coming years.
* Non-conventional energy equipments are exempt from sales-tax and excise-duties.
* 5 years tax holiday is applicable to power generation projects.
* 100% depreciation is allowed in the first year itself for all non-conventional energy projects.
* Non-conventional energy-based power projects are allowed wheeling and banking by State Electricity Boards (SEBs) at a nominal rate of 2% on an annual energy basis.

* Power purchase agreements with SEBs on attractive terms and with necessary Government guarantees on mutually agreed terms.
* Soft loan facility from IREDA.
* Loan facilities from other financial institutions.

15.2 By establishing linkages with industry associations, chambers of commerce etc., MNES plans to bring about greater awareness of renewable energy devices and utilize their forums to activate industries for establishing manufacturing plants, power projects and joint ventures. MNES is trying to establish linkages with user Ministries for promoting applications of renewable energy technologies in organizations under these ministries. One example of such initiative is with Ministry of Urban Development, for making it mandatory to use solar water heating systems in Government establishments which otherwise use conventional energy.

15.3 MNES' commercialization strategy also includes demonstration projects on cost-shared basis, wherever such demonstrations are likely to spur commercial activity, which otherwise may not materialize quickly.

16.0 ROLE OF INDIAN RENEWABLE ENERGY DEVELOPMENT AGENCY (IREDA)

16.1 IREDA was set up in 1987 as a financing body to extend soft loans to renewable energy projects. Over 200 projects have so far been financed by IREDA. With equity support from

the Ministry and some grants from Dutch Government and GEF, IREDA has built up a sizable portfolio of nearly $200 million. This includes the World Bank's assistance under IBRD, IDA and GEF mechanisms. IREDA has also been allowed to raise funds from the market and seek association of other financial institutions in co-financing.

16.2 The capabilities of IREDA in project appraisal, monitoring and management are being strengthened IREDA will play an increasing role in promotional activities including information dissemination, entrepreneur development, training, project financing and technology upgradation.

17.0 INTERNATIONAL COOPERATION

17.1 In the past, bilateral projects in renewable energy were undertaken mainly within the framework of Science & Technology cooperation agreements and were limited to R&D and demonstration projects. These projects served a limited purpose, and could not spur market development or foreign investments in joint ventures in any way. Perhaps, a major exception is the Danish (DANIDA) assistance for wind farm projects which was fairly large, well directed and led to licence agreements for production of wind turbines in India with Danish industry collaborations.

17.2 A significant breakthrough occured in 1987, when the World Bank carried out a study on opportunities for commercialization of non-conventional energy devices in India. This was followed up by MNES and the World Bank,

which ultimately culminated in a project titled 'Renewable Energy Resources Development', with a combination of IBRD, IDA credits and GEF grants totalling about US $ 195 million for three project components, namely, windfarm development, PV market development and small hydro power development. These projects are likely to attract further donor support from DANIDA, Swiss Development Cooperation and others. IREDA has been chosen as the implementing agency and the project has already been launched. The financing arrangements and lending rates vary from 5% for PV systems to 14.5% for wind farm projects.

17.3 Several investment proposals and joint venture projects have been mooted by entrepreneurs in India and outside and both State and Central Governments are keen to provide necessary facilities to enable further progress to be made, in this regard. Wind farms, solar thermal and PV power plants, small hydro, bagasse cogeneration are the areas that are actively being pursued. Joint ventures for establishing production are also receiving attention. Bilateral and multilateral cooperation activities are expected to increase in view of liberal economic policies introduced by the Government.

17.4 A technical assistance programme supported by ADB will be initiated soon. It seeks to explore opportunities for ADB credits for solar water heating, energy from urban and municipal wastes and rural energy schemes.

17.5 The United Nation's Development Programme, FAO, UNESCO have been evincing keen interest and extending support for projects in renewable energy in India. It is expected that UN-supported activities will increase with the growing concern for environment and sustainable development.

18.0 <u>SOLAR ENERGY CENTRE</u>

18.1 The Solar Energy Centre under MNES, located on a sprawling 200 acre land area about 30 kms. from Delhi is in the process of building up facilities and manpower. At present, it is engaged in testing and standardization work as well as training of manpower. It has established a [illegible] indoor/outdoor test facility for solar collectors. National Photovoltaic Test Facility has recently been established at the Centre. It is envisaged that with further augmentation of facilities, the Centre will grow into a Centre of Excellence involving itself in R&D, documentation and dissemination of information, training, technical consultancy and acting as an interface between R&D, industry and users.

19.0 <u>CONCLUSION</u>

19.1 Renewable energy development is considered in India to be of great importance from the point of view of long-term energy supply security, decentralization of energy supply particularly for the benefit of the rural population, environmental benefits and sustainability.

19. For India and for many other countries faced with twin challenges on energy and environmental fronts, renewable energy is bound to play an increasing role in future energy systems.

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Renewable Energy Technologies: Economics and Potential

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Renewable energy programmes in India

A brief review of experience and prospects

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Efforts towards the development and deployment of technologies based on renewable energy sources in India are described. A brief review of renewable energy programmes with an emphasis on the specific strengths of the different programmes in the context of India's renewable energy programme is presented. Renewable energy systems which appear to have a significant role to play in the sustainable energy programme of India are identified and their implementation discussed.

The attempts of developing countries to deploy technologies based on renewable energy sources have had their problems and false starts. An example is the Chinese biogas programme that constructed over seven million small biogas plants in a three year period. Within a short period of time, however, over half of them were out of operation and it is only now that the programme is recovering from its early promotional phase through qualitative changes in the concept of biogas utilization [10]. It is clear that developing countries could benefit substantially by sharing with each other their past experiences with renewable energy sources. India, for example, has a biogas programme which could approach the Chinese biogas programme in size and the Rs 700 million (US$1 = Rs30) spent annually on the programme is likely to be better utilized by learning from the Chinese experience. On the other hand, India's impressive performance in installing and maintaining windfarms has its own lessons to teach. The objective of this article is therefore to document the efforts towards development and deployment of technologies based on renewable energy sources in India. A brief review of India's renewable energy programmes is presented with an emphasis on the specific strengths of the different schemes in the context of a larger renewable energy programme. Specific programmes which appear to have lessons for the larger goal of establishing sustainable energy systems in developing countries are discussed.

Government support for a renewable energy programme in India

The new and renewable sources of energy (NRSE) programme in India started in earnest with the establishment of the Department of Non-conventional Energy Sources (DNES) in 1982. Started as a modest programme with an annual outlay of about Rs 43 million in 1980/81 (Table 1), the first year allocation of the 7th Five-Year Plan (1985–90) was nearly equal to the total outlay during the five years of the 6th plan (1980–85) [7]. In spite of the sharp increase in funding for renewable energy technologies, the fund allocation has remained small in comparison to the financial outlay for the energy sector as a whole. Between April 1980 and March 1992, the total cumulative government expenditure in the renewal energy sector amounted to Rs 115 500 million. By comparison during the same period the government invested over Rs 812 000 million in the power sector, over Rs 335 000 million in the petroleum sector and about Rs 158 000 million in the coal sector (see Table 1).

Despite the relatively small investment in the renewable energy sector in the early 1980s, the trends in investment appear encouraging. Using 1980/81 as the base, the investment in renewables in 1988/89 was higher by a factor of over 30, whereas investment in

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Table 1 Summary of expenditure in the energy sector (Rs × 10^9)

Plan	Year	Power	NRSE	Petroleum	Coal	Total
Sixth Plan	1980-81	26.57	0.04	7.35	4.32	38.28
	1981-82	31.82	0.14	12.05	6.64	50.65
	1982-83	37.09	0.23	18.23	8.56	64.10
	1983-84	40.93	0.34	21.98	9.53	72.77
	1984-85	46.59	0.89	25.21	9.04	81.72
Seventh Plan	1985-86	56.16	1.33	28.70	9.95	96.13
	1986-87	67.01	1.42	33.26	12.33	114.03
	1987-88	70.96	1.16	30.20	13.63	115.95
	1988-89	82.44	1.36	31.09	17.38	132.26
	1989-90	102.38	1.37	36.84	17.94	158.53
Annual Plan	1990-91	113.34	1.42	41.30	23.92	179.99
Annual Plan	1991-92	136.78	1.87	49.17	25.20	213.02
Sixth Plan (1980–85)						
Total expenditure	1980–85	182.99	1.63	84.82	38.08	307.51
Total plan allocation	1980–85	192.65	1.00	43.00	28.70	265.35
Surplus (+) deficit (−)	1980–85	−9.67	0.63	41.82	9.38	42.16
Seventh Plan (1985–90)						
Total expenditure	1985-90	378.95	6.63	160.09	71.22	616.89
Total plan allocation	1985-90	342.74	5.20	126.28	74.01	518.33
Surplus (+) deficit (−)	1985-90	225.15	3.12	118.61	39.35	416.10
Cumulative expenditure	1980–1992	812.06	11.55	335.38	158.41	1317.41

Note NRSE = new and renewable sources of energy
Source *Economic Survey 1991-91* Part II (Sectoral development) MOF [6] - pp S 50 S–48

the other energy sectors was higher by factors of only between 3 to 4

Proposed renewable energy plan till 2000

Perhaps encouraged by the trend in increased funding mentioned above the DNES proposed an extremely ambitious plan [2] for renewable energy utilization by 2000 01 Published in early 1987, the DNES plan proposed a total expenditure of about Rs 435 000 million by 2000 01 A total of 15 425 MW of renewable power generation capacity is proposed with 5 000 MW from windfarms 2 000 MW from small hydel and 2 000 MW from solar thermal conversion

The cost of the DNES s proposals would be quite high The biomass route to power generation would require the largest investment of all Adding the cost of establishing energy plantations the total cost for biomass power generation is approximately Rs 105 000 thousand million (nearly the same as the cost for the biogas programme) The investment proposed for windfarms is estimated at Rs 75 000 million while the Rs 60 000 million proposed for solar thermal-electric conversion would be Rs 20 000 million higher than the amount required to set up the same 2 000 MW of power generating capacity using conventional sources of energy

Funding within the renewable sector: 1985–90

In order to judge the likely funding in the years to come and the ability to implement the programmes proposed by DNES, it is important to examine the trends in the funding of the different renewable energy technologies and their achievements in the recent past As shown in Table 2 the biogas programme has accounted for nearly half of the funds allocated to the renewable energy sector during the period 1985-90 The total expenditure on the biogas programmes in the past four years has been over Rs 2 362 million (Table 3) In the past four years the improved cook stove and the solar photovoltaic programme have received a total of about Rs 360 million each, while solar thermal biomass, and wind energy programmes received allocations in the range Rs 250–300 million

Significant changes in the funding structure are envisaged in the DNES plan for the coming decade Some of the major changes proposed are

(i) The biomass programme is to become a major programme From receiving 6% of the funding during the past four years the share of the biomass programme is expected to jump to 19% Including energy plantations, the total share of the biomass programme will be 40% of total government funding for renewable energy

(ii) The share of expenditure for biogas is planned to be cut drastically from the present 54% to 16% by 2000

(iii) The wind energy programme is likely to be expanded significantly accounting for about 19% of all the funds earmarked by the government for NRSE Presently the wind energy programme gets about 6% of the funds, but judging by the impressive performance of the windfarms

Table 2 Trends in allocation by programmes (Rs × 10⁶)

	1986/87	1987/88	1988/89	1989/90	Total 1986–90
Biogas	682.5	481.5	574.3	624.5	2362.8
Improved cookstove	60.0	87.4	99.2	119.0	365.6
Solar photovoltaic	79.5	86.0	95.0	102.5	363.0
Solar thermal	81.5	68.3	62.5	80.2	292.5
Biomass	61.5	80.0	60.0	49.6	251.1
Wind energy	60.0	69.9	54.8	59.8	244.5
Other programmes	25.0	28.1	24.5	38.5	116.1
Energy from wastes	35.0	24.0	22.5	11.4	92.9
State agencies IREDA	20.0	-	25.0	32.5	77.5
MHD	20.0	20.0	12.5	5.0	57.5
Secretariat	13.0	5.1	14.3	12.9	45.3
Information public awareness	6.8	8.5	3.8	4.7	23.8
Urjagram	8.2	7.5	2.2	2.2	20.1
Regional offices	1.0	3.0	4.0	5.0	13.0
Grand total	1154.5	1001.3	1054.8	1157.4	4368.0

Note: totals may not match due to rounding errors and exclusion of minor accounting heads.
Source: Annual Reports, DNES [1], Government of India, various years.

in India (discussed subsequently), the increase in funding for this programme seems logical.

(iv) The small hydel programme is also to be expanded significantly in the coming decade. The fund allocation for the small hydel sector is proposed to be raised from the negligible levels in the past four years to about 9% of the Rs 435 000 million to be spent on NRSE.

As mentioned earlier, the proposed plan of the DNES is at best optimistic. The government funding sought is over Rs 403 500 million for the 8th Five-year Plan (1992–97). Up to 2000, the DNES proposes to spend nearly Rs 117 800 million of the total estimated investment of Rs 435 000 million of government funds – the balance coming from the public. Clearly, this level of investment from individuals assumes that the requisite acceptance of the technologies by the public has been achieved or that it will be forthcoming in the near future. For this reason it is important to review the economics and experience in implementing technologies based on renewable energy sources in India.

Cost of renewable energy technologies in India

There appears to be some dispute over the economics of renewable energy technologies in India, with divergent views on the estimates of its cost. Part of this divergence arises from the traditional supply orientation of past energy planning, which has emphasized development of the power, coal and hydrocarbons supply industries without adequate regard to the total demand for these and other forms of energy. Not accounting for renewable energy technologies and not viewing demand in the form of specific end uses is still common among those responsible for formulating energy plans in India [14]. The social cost of supply of conventional fuels is often underestimated as well.

On the other hand, proponents of renewable energy technologies often assume ideal conditions in the operation, maintenance and performance of renewable energy devices. In this paper we attempt to include all the costs of conventional energy in relation to alternative forms of non-conventional energy. Therefore operational, organizational and other factors which might actually reduce the merit of renewable energy technologies are included in the data presented here.

The costs associated with some of the more promising technologies based on renewable energy sources are summarized in Table 3. Estimates of the true (but quantifiable) costs of conventional energy conversion routes are also summarized. For comparison, the costs are presented in two categories – centralized power generation and decentralized power generation for similar energy end-uses. The technologies and the conversion routes listed are selective and the intention here is to present an indicative comparison rather than a comprehensive one.

As indicated in Table 3, small hydel and windfarm power generation offer the most cost-effective renewable energy options. For decentralized applications the cost in Rs/kWh ranges from Rs 0.4 (for biogas based dual-fuel systems) to Rs 12 for photovoltaics. It should be pointed out that the international market price of PV modules has been used in the computations along with the appropriate market exchange rate for the US$.

Experience with renewable energy technologies: 1982–90

A dispassionate look at the renewable energy technologies (RET) programme in India would indicate that there are some technologies (namely grid connected wind turbines and solar cookers) which have achieved

Table 3 Summary of the cost of energy from various technologies

Technology	Unit	Capital cost (Rs/unit)	Useful life (years)	Cost CRF (@)	Annual capital cost (Rs/unit/year)	Recurring costs O&M (#) (Rs/unit/year)	Fuel (Rs/year)	Total annual cost (Rs/year)	Annual generation (*) (kWh/unit)	Cost of energy (Rs/kWh)
Centralized power generation										
Renewable technologies										
Wind farm	kW	30000	20	0.134	4016	1500		5516	1752	3.15
Solar thermal	kW								1100	
Central receiver system		125000	20	0.134	16735	2500		19235		17.49
Line focusing system		80000	20	0.134	10710	2400		13110		11.92
Small hydel	kW	30000	30	0.124	3724	600		4324	2628	1.65
Coal thermal	kW	15000	25	0.127	1912	375			4818	
Cost of coal with coal transport @Rs 0.26 t/km) and marginal pit-head cost of Rs 235/t for										
	300 km	313 Rs/t					1953	4241		0.88
	500 km	365 Rs/t					2133	4421		0.92
	800 km	443 Rs/t					2404	4691		0.97
	1000 km	495 Rs/t					2584	4872		1.01
Decentralized power generation										
Stand-alone wind turbines	kW	60000	20	0.134	8033	8190		16223	2190	7.41
Photovoltaics	kWp	110000	25	0.127	14025	4220		18245	1560	11.70
Gasifier[b] Agro-waste based	kW	9500	15	0.147	1395	950	4415	6760	5256	1.29
Wood based	kW	7500	15	0.147	1101	750	5992	7843	5256	1.49
Biogas dual fuel	kW	9500	20	0.134	1272	950		2222	5256	0.42
Solar dish stirling	kW	90000	20	0.134	12049	1800		13849	1752	7.90
Contribution of distribution line for different distances from the 33 kV grid	km									
	1	43000	25	0.127	5482	2150		7632	30660	0.25
	5	215000	25	0.127	27412	10750		38162	30660	1.24
	10	430000	25	0.127	54825	21500		76325	30660	2.49
	15	645000	25	0.127	82237	32250		114487	30660	3.73
Irrigation/shaft power										
Windmill[c]										
Shallow well unit		25000	20	0.134	3347			3347	1000	3.35
Deep well unit		45000	20	0.134	6025			6025	1200	5.02
Gasifier[d] Agro-waste based	kW	14085	15	0.147	2068	1408	2208	5684	2628	2.16
Wood based	kW	12085	15	0.147	1774	1208	2996	5978	2628	2.27
Photovoltaic[e]	kWp	230000	25	0.127	29325	3450		32775		
Irrigation		(demand restricted to 120 days/year)							624	52.52
Water supply		(constant demand throughout the year)							1560	21.01

[a]See TERI [16] [b]See Kishore and Sinha [6] [c]See Sinha and Kandpal [13] [d]See Sinha and Kandpal [14] [e]Includes lead-acid battery storage costs of Rs 2/kWh for wind and solar stand-alone systems. Assumed annual mean daily solar insolation 5.2 kWh/m. See Sinha and Kishore [15]. Discount rate of 12% used

a high level of reliability and user acceptance Government support for those technologies in terms of a subsidy is required only to correct the distortions in the pricing of conventional energy sources There are others (such as gasifiers windmills solar hot water systems) which are nearing the commercialization stage and for those government support is required for demonstration projects and further work on enhancing reliability Then there is a group of technologies somewhere in between the two Those technologies have achieved a fair degree of maturity but their diffusion suffers due to the manner in which they are promoted Biogas, small hydel, improved cookstoves are some technologies that fall into this category Finally, there are several technologies which still seem to require an extensive R&D effort and/or substantial cost reduction

In the past decade in India (and many other developing countries) many of the new RETs have been forcefully promoted as solutions to energy problems before the technology reached a level of maturity that warranted such promotion In India aggressive promotion led to unreasonably high expectations from RETs and the promotional effort, either explicitly or implicitly, gave the impression that those technologies were the answer to all the energy problems of the country Ironically today those past efforts have resulted in the greatest barriers to the introduction of RETs As a consequence there is a widespread feeling among those associated with energy planning that RETs and their possible role is grossly overrated This situation is not unique to India and an excellent summary of the perceptions regarding the role and the relevance of RETs can be found in Grubb [4]

One result of overrating RETs in the past is that when some of the renewable technologies have actually achieved a level of maturity, proponents of those technologies encountered few planners with faith in their viability Clearly, unambiguous statements of the constraints and the strengths associated with different renewable energy technologies are called for in order to regain credibility for those technologies In India effort needs to be devoted to a serious assessment of what current technology is able to achieve and to arrive at a realistic estimate of the potential for those technologies within the context of an overall energy system Unfortunately, there seems to be an inadequate appreciation of the reasons for the indifferent performance of some renewable energy technologies by those managing projects The gasifier programme in India is a good example As indicated earlier DNES has proposed to expand this programme to such levels that it would become the largest programme in the renewable energy sector However to date there is very little experience in gasifiers with a capacity above 10 kW Furthermore experience has been largely restricted to wood gasification and the experience in the past few years indicates that there are major difficulties in obtaining a steady supply of feedstock because of the scarcity of wood An attempt, therefore, is being made in India to develop gasifier designs that utilize a wider variety biomass feedstock (such as agro-residues) Developing that technology to achieve commercialization, however, may require from 3–10 years (depending on the R&D funding levels) An attempt to seek massive funding for a gasifier technology at its present level of development, as is being proposed by DNES, will invariably lead to a significant loss of credibility for other technologies in the renewable energy sector

For the renewable energy programme to make a significant contribution to the energy scene in India firm priorities must be set Technologies which are mature and reliable must be promoted with vigour For some, the implementation aspects must first be re-evaluated Others require specific R&D efforts related to a particular feature of the system As implemented today in India, the RET programme is extremely diffuse and seems to be moving in too many directions at once

Specific features and the realistic potential of some of the more promising technologies for India are discussed below Particular emphasis is given to windfarm power generation and small hydel power generation because those two technologies have reached a level of maturity that merits such discussion

Wind energy utilization

In India windfarm power generation has the potential to make the most visible contribution The technology is mature, cost-effective and has proven its ability to deliver power The estimates of its potential vary, but all are placed above 10 000 MW Though there are indications that the government is now targeting for 1500 MW there appears to be no reason why the installed capacity of wind turbines cannot reach 5000 MW by the turn of the century if concerted efforts are made and if the requisite funds are available The recent proposals to open the power sector to private investors is likely to provide impetus to the diffusion of this technology There are however, some lacunae in the proposed modifications of the existing legislation Perhaps the most important among them relates to the arrangement to buy and sell power from private sector companies

The major impediment to wind energy utilization in India is likely to be the restriction in the funds available for the whole renewable energy programme The upper limit to the cumulative capacity of turbines that

are likely to be installed will depend on the funds allocated and possibly the availability of wind electricity generators (WEGs) The technology is mature (though not completely indigenized) and has proven itself particularly in the past 4 5 years

The achievements in India in the past few years in installing and operating windfarms for power generation have been impressive though far short of targeted levels Of the 140 MW of windfarms planned for the period 1985 90 only 31 MW were installed Noteworthy, however in this context is the installation of 20 MW of windfarms in one year (1988 90) Of the 2000 MW targeted for 1990–95 23 MW was expected to be installed by March 1992 bringing total capacity to 54 MW

The figure of 2000 MW installed by 1995 is higher than the current capacity of windfarms in any other country That figure therefore needs to be reviewed in the context of the availability of wind turbines in the international market With nearly 1500 MW California at present has the largest installation of windfarms Those installations were achieved in about eight years but such activities as resource assessment, R&D and formulation of rules and regulations to buy sell power to utilities etc have been going on since the mid-1970s In India technical experience is limited to demonstration windfarms and though the technical capabilities to evaluate sites and to prepare detailed project reports with layouts etc are available, to carry out this activity on a large scale in the time envisaged is likely to prove to be a formidable task (see [5] for more details)

Another lesson from the California experience needs to be appreciated The peak rise in windfarm installations in the period 1983–85 with an average annual increase of about 400 MW, was largely accomplished (about 60%) with domestically manufactured turbines and equipment Domestic production facilities in India and elsewhere in Asia are almost non-existent Assuming that the sites have been identified the ability to import WEGs would be determined by the production capacity of international suppliers An annual production of 500 MW to meet India s needs appears to be high in the context of present shipments of WEGs In this context it may be worthwhile to note that the installations of wind turbines in the European Community (EC) countries increased from 10 MW in 1981 to 215 MW in 1989 implying an annual increment of about 23 MW year In the EC the highest installation rate was in 1986–89 with a total of 30 MW The projected installations in the EC countries are much more ambitious – the cumulative installation by 2010 is expected to reach 12 100 MW The incremental installation therefore, is about 600 MW every year

In addition to the factor of the availability of WEGs to meet India s needs there is also the need to integrate windfarms into the existing power system The ability of an existing power system to absorb an intermittent generating source depends on a host of factors and the importance of such factors as the existing generating capacity-mix in determining the technical mix of such intermittent sources needs to be appreciated Moreover it should be noted that unless a special effort is made towards meeting assigned targets the actual number of installations will fall short of those targets by a significant amount

While it is important to appreciate the difficulties of wind energy utilization it is equally important to bear in mind that the phenomenal increase in wind powered systems in the 1980s all over the world was not foreseen in even the most optimistic projections made in the early 1960s or 1970s Most of the difficulties outlined above are surmountable with concerted efforts and a short gestation period In addition the modular nature of the WEG technology permits rapid assimilation and design correction permitting a quick transfer of field experience to improvements in the technology The implicit assumption in such improvements in technology however, is the involvement of domestic manufacturers in the technology At present however, India s production of wind turbines leaves much to be desired Only three industries in India are licensed to manufacture wind turbines With recent liberalization of the industrial policy (starting in the second and third quarter of 1991) however positive changes are expected In spite of this, it is unlikely that India s manufacturing capability will exceed 50 MW per year in the short to medium term (by 1995) even if steps were taken today Assuming that world production facilities can meet another 150 MW of the Indian requirement the annual increment in wind power in India can be at best, 200 MW in 1995 96 and thereafter

Most of the technical problems of converting wind energy into useful power and of successfully deploying the technology relate to the peculiar nature of wind as a resource The output from the wind energy conversion devices is proportional to the cube of the wind speed Coupled with the high degree of variability of wind speed from site to site the siting of wind energy conversion devices becomes extremely important For example a survey in India in 1985 [8] found that of 177 water pumping windmills installed in eight different states 106 of them were sited at locations with inadequate wind and water Though the survey was confined to water-pumping windmills the installation of wind electric converters requires similar care in selecting the site for installation The recent trends in more rational siting however are encouraging

Table 4 Summary of small hydel potential (identified sites)

	Total capacity (MW)	Estimated cost (Rs × 10^9)	Installed cost (Rs/kW)
Mini hydel schemes	980.46	21.17	21594
Canal drop schemes	148.71	3.33	22388
Total	1129.17	24.50	21699

There are indications that over 85% of the windmills installed in India in the past three years, are located at suitable sites (see [14] for more details). It must also be noted that the technology associated with stand alone wind electricity generators in the capacity range of 1–20 kW is fairly complicated and expensive. This is mainly due to the requirement for a large and expensive capacity for electrical energy storage, and this, in turn requires the use of sophisticated storage techniques (such as deep discharge batteries) and battery control and regulation facilities. Also, the turbines are expected to work with standard AC equipment which requires a large inverter.

The problems associated with WEG systems are similar to those associated with PV systems. Most renewable energy systems in the 1–20 kW power range, so far have yet to prove their reliability [3].

By contract, at present, the technology for small turbines (of less than 500 W) is mature and cost-effective. The small turbines use specially designed low-speed brushless, permanent magnet alternators coupled directly to the wind rotors. Those have been extensively used world-wide and have proven their reliability though they remain largely untested in India.

Small hydel

In India micro mini small hydel is another technology with enormous potential. Up to the beginning of 1990 installed small hydel capacity exceeded 25 MW and work on an additional 82 MW was underway. Additional sites have been identified and there appears to be little reason why within the next decade total operational capacity cannot exceed 1000 MW (Table 4) provided there are adequate policy initiatives. Like wind energy utilization this is another technology which may benefit greatly from more explicit legislative guarantees regarding purchase/selling of generated power to state utilities by private sector participants. At this moment, however, it is difficult to estimate the likely penetration of this technology beyond 2000. Obviously much depends on the experience with the programme in the next decade.

Currently however, the perception among those responsible for decision-making in the Indian energy sector is that small hydel is unreliable and of high cost. Those two factors combined have raised doubts about the possible role of small hydel in the Indian energy mix. As is discussed below reliability of the small hydel system can be substantially increased through the innovative and interlinked design of small hydel facilities. According to a recent World Bank survey of the technical designs of small hydel facilities it is possible to bring down the unit cost of small hydel plants to one third of the current cost (which is currently in the range Rs 25 000–30 000 kW) by a combination of design modification and standardization of the equipment which would permit economies of scale in manufacture.

Among those who have examined the issue in India, it is felt that the initial batch of small hydel schemes in India were conceived, designed and executed as scaled-down versions of large conventional hydel installations. As a result there were numerous redundancies in the designs for key features, such as the layouts for the civil works, the facilities incorporated into the powerhouse structure, the selection of turbine-generator equipment, and the specification of the electrical switching and protection system. Some of the high costs associated with small hydel were a result of the long gestation period of the projects. These in turn, were caused by the complex layout of the schemes. Part of the high costs in the initial schemes was also due to the unnecessarily high level of technical manpower used to operate and maintain the pilot schemes. Needless to say, all these additional costs can be reduced substantially, thereby dramatically altering the economics and the potential importance of small hydel.

There are other measures which can result in further improvement in small hydel, but they will require a longer time frame to implement. The design of small hydel projects on a river basin basis by applying the principle of cascade development, like the Chinese small hydel programme, can be a major factor in increasing the potential and success of the Indian programme. In planning small hydel projects for small river basins the emphasis should be placed on evolving designs to take advantage of the topography and to arrange the hydropower structures such that the headwork (or the intake) of one station follows closely the tailrace (open canal for tail water) of the other. The upstream regulating reservoirs can then be designed so that the cascade process raises the dependability of the whole basin system. Such cascade systems which can generate as much as 10–20 MW can then be integrated to form a local grid. Those local grids, in turn, may be connected to a regional grid. Small hydel developed in this fashion can result in rural electrification that is fundamentally different from that of today electrification will not simply be

Table 5 Summary of deployment of renewable technologies in India

	Unit	Installation in India	Date
Biogas programme (NPBD)	Number	1 400 000	31 March 1991
Cookstove programme (NPIC)	Number	10 300 000	31 March 1991
Solar hot water systems			
Domestic	Number	6 692	31 July 1991
Total collection area	m	174 000	31 March 1991
Solar cookers	Number	180 000	31 March 1991
Solar photovoltaics			
Total systems	Number	34 000	31 March 1991
Total systems	kWp	4 000	31 March 1991
Power plants	kWp	593 7	31 September 1991
Windmills (irrigation)	Number	2 710	31 March 1991
Windfarms (power generation)	MW	37	31 March 1991
Waste recycling plants	Number	697	31 March 1991
Mini micro hydel			
Commissioned	kW	550	31 March 1991
Under installation	kW	15 000	

Source DNES

the extension of large grid systems, but rather the gradual interlinking of many small, but growing, local grids This can have a profound impact on the way in which rural electrification is visualized and implemented, in addition to raising the dependability of small hydel facilities

The standardization of hydroelectrical equipment, (water turbine-generator combinations) through establishing technical specifications and the consequent improvement in the quality of manufacture and reduction in unit costs by making production in batches possible, is another measure that can go a long way to make implementing small hydel reliable and quicker This is likely to have another favourable spin-off China is a good example Measures to standardize designs of the equipment for small hydel stations in China started in 1978 The result of this ongoing and evolving exercise was the standardization on four types of turbines, eight runner series and 32 product varieties About 85% of the all components now have standardized designs making the production process economical and the components reliable The standardization process has resulted in products in the capacity range of 500–10 000 kW suitable for water heads of 3–450 m (See [9] for more details) By 1989, the estimated number of hydroelectrical manufacturers in China reached 100 and annual production capacity exceeded 1 000 MW

Biogas programmes

Established biogas programmes in India such as the National Programme on Biogas Development (NPBD) have gathered a momentum of their own At present the number of biogas plants exceeds 1 4 million units and in size is next to the cookstove programme which has more than 12 million units in use (Table 5) Although some evidence suggests that both of those programmes are not without their share of problems there seems little reason to doubt that both will remain the cornerstone of a renewable energy programme in India In the past both programmes have constantly exceeded their targets and the infrastructure which has been created to support them is strong (but not necessarily responsive) The programmes would benefit greatly from a greater attention to the detail of deployment and on developing lower cost systems and infrastructure for post installation repair and maintenance

It is generally agreed, however that the technology has worked well wherever biogas has replaced commercial fuels and where there is a financial saving from its use In most cases, the malfunctioning of a biogas plant can be traced to inadequate attention being given to the routine maintenance of the plant The problems associated with the biogas technology can be classified as technical, operational or institutional

Technical problems Among the different biogas plant designs, the failure rate of fixed dome (Chinese design) biogas plant is higher than that of the floating (metal) dome design The reasons for this are twofold

(i) There is a problem with the availability of quality construction materials The grade of cement and bricks required and the kind of sand recommended for the construction of the fixed dome design which would guarantee trouble-free operation, are difficult to come by
(ii) The skill of the mason is important especially for constructing the dome of the fixed dome plant

Operational problems. Most of the operational problems of biogas plants relate to the feed-stock material. The usual problem is the lack of the amount of dung required for input. What often happens is that when estimating the capacity of the biogas plant that can be supported by the household, the number of cattle is often used as the sole criteria and the grazing practices which effect the actual availability of dung are not considered. As a consequence, the amount of input feed is lower than that required, leading to a low production of gas, and therefore low pressure in the output biogas along with a host of problems related to low gas pressure.

Institutional problems. The planning and construction of a biogas plant has several organizational problems associated with it. In fact, many of the problems are common to other decentralized renewable energy options. The main problems are:

(i) waste associated with the arrangement of loans and subsidies and the excessive amount of time spent finding the proper material for construction (mostly cement);
(ii) finding masons with the requisite skills for constructing the biogas plant; and
(iii) the lack of competent technical supervisory staff to advise on construction and to provide follow-up services.

Gasifier technology

The field performance of biomass gasifiers in India is not very well documented. The relevance and reliability of gasifier technology, though now considered nearing commercialization, is therefore difficult to evaluate. A study of 67 installed systems which had together clocked 17 500 hours (an average of just 290 hours year each) reported that two systems had failed completely. Four systems had, however, reported more than 1000 hours of trouble-free operation. At this point in time it is difficult to gauge the reliability of the technology due to limited operational data.

Despite the limited field data on reliability, significant developments have taken place in gasifier technology in India in the past decade. An evaluation of those developments is called for in order to chart out a future direction for the commercialization of this technology. In India two options appear particularly attractive. For small-scale decentralized applications, the use of a self-contained multi-feedstock (mainly agricultural residues) briquetting machine coupled with a gasifier appears to hold the most promise. In cases where a multi-modal application is possible, the economics of the gasifier show a marked improvement. The second attractive option for gasifiers is for power generation in the capacity range 100–500 kW wherever sufficient wastes are available (such as agro-industries). The experience at that power scale, however, is limited.

Conclusions

As implemented today, the renewable energy programme in India is moving in too many directions at once. For renewable energy programmes to become more effective in developing countries such as India, firm priorities must be set. Technologies which are mature and reliable must be promoted with vigour. For some, the implementation aspects need to be re-evaluated. For others, specific R&D efforts related to particular features of a system need to be promoted.

In India, a change from an emphasis on numbers and targets rather than on the quality of the implementation of the programme is urgently called for. The Indian experience indicates that deployment strategies that focus on concentrated deployment rather than widespread deployment is what is required. In the rural sector, the emphasis should be on intensively implemented programmes in a geographical cluster of villages where energy (or the lack of it) is perceived to be an issue. Such an intensive approach would permit greater emphasis on providing post-installation attention to the installed devices. Some of these changes would require restructuring implementing organizations in India so as to place more emphasis on post-installation services. In other developing countries, these issues must be borne in mind while formulating and implementing renewable energy programmes.

The creation of an indigenous renewable energy technology manufacturing infrastructure is another crucial requirement for an effective renewable energy programme. Innovation within the (existing or new) manufacturing industry will have to be encouraged through reducing government control and reducing direct subsidies. The latter is particularly important for other developing countries. Experience in India suggests that direct subsidies more often than not inflate the profit margins of influential manufacturers at the cost of quality. In this regard, fiscal incentives have been found to be more effective. Similarly, removal of subsidies on conventional sources of energy is likely to have greater impact than additional subsidies for renewables, something that has been learned in India from the dissemination of solar hot water systems.

Concerted efforts to demand a higher share of investment for research and development on RETs and for increased deployment of RETs are still

Draft

Accounting for Natural Resource Depletion & Degradation

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Background

Most production and consumption activities require inputs in the form of natural resources, human resource, and invested capital (land, labour and capital) A skilled application of energy to these natural resources transforms them into useful commodities which are returned to the environment after fulfilling the purpose of their production. The systematic accounting of all these transformations and related transactions came to be known as National Income Accounts The System of National Accounts (SNA) advocated a prudent economic management by governments so that the maximum national level of consumption could be marked without eventual impoverishment These accounts were first published in the United States in the year 1942 Today SNA is being practiced by almost all the countries in the world They are not only the sole parameters of gauging economic performance and, therefore, the success or failure of prevailing economic policy decisions but also guide the formulation of future policies

Current National Income Accounting and its Shortcomings

True income is the maximum amount which the recipient can consume in a given period, without reducing potential for consumption in the future periods This concept is applicable not only to current earnings but also changes in the ownership of assets - while capital gains are a source of income, capital losses reduce income (Daly 1986, El Serafy 1981, 86)

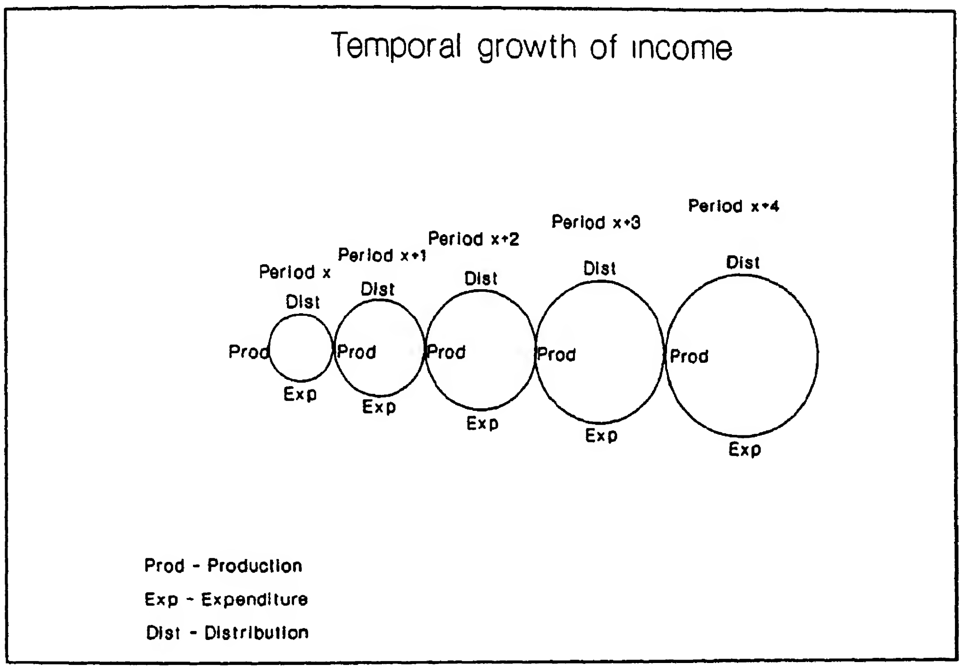
SNA treats revenue derived from the sale of natural resources as current income or rent that is available for consumption When this revenue accrues to the public sector, it can be used just like any other source, such as the proceeds from income taxes. This revenue generated by liquidating a country's natural assets is neither recurrent nor sustainable Let us consider the example of India's forests The forests of a country are a national economic asset capable of producing important economic benefits, directly through the generation of

marketable products like timber, fuelwood, fodder, grasses, small timber,and non-timber forest products viz gums, resins, oil-seeds, flowers, tendu leaves, etc and indirectly through watershed protection, environmental stability, tourism, and other activities that depend upon the forest's existence. In India, over exploitation of the forests over the years, massive pressure of grazing in the forest areas and diversion of forest lands for non forestry purposes like agriculture, construction of dams etc. has depleted it's forest wealth substantially This can be undoubtedly gauged from the fact that whereas at the time of independence 33% of the forest land was under forest cover, today only 19 % (official estimates) has any forest cover left, of which most of the area are degraded forests or are scrub lands Despite the massive returns being generated by this natural resource, less than 1% of the total plan outlay finds itself allocated for this resource. Moreover, such an alarming decline in the forest area and the decline in its productivity may not be able to sustain the current rate of extractions

National Income Accounting can be defined as a set of systematic statistical statements which reflect the value of the total final output produced in various sectors of the economy such as agriculture, industries, transport, trade, banking etc together with details of distribution of factor income among different groups and final expenditure of the economy in a given period

Generally, the economic development of any country is expressed in terms of growth of its income National income considers both physical flow of goods and services and a monetary flow, a circular flow, beginning with the process of production generation of income and its distribution among the factors of production, and finally, expenditure on them on acquisition of goods and services or savings and thus investment The long run tendency of the rounds of production, distribution and expenditure is to increase, and for the national income as a whole to grow reflecting the underlying tendency of the population and of the productivity of nation's capital and labour to grow However, the temporal growth of income is notional and illusory The conventional UN system of national accounts have a dangerous anomaly inherent in them They record man-made assets - such as plant and machinery, buildings, etc , as productive capital, which are written off against the value of

production, as capital depreciate on a year to year basis. This practice ensures that a part of physical capital gets used up in the course of production, the depreciation allowance accumulates to provide for the replacement of this man made capital stock at the end of its life However, natural resource assets are not so valued, and their loss entails no negative charge against the current income which gets generated as they are consumed, thus reducing potential future production



With specific reference to the diagram above, the flow of income and expenditures in the economy will be affected by the extent to which "linkages" in this flow are matched by new injections into the flow to ensure a steady growth of national income While the consumption of man made capital is accounted for as costs and depreciation allowance kept aside for its injection in the subsequent period, no such allowance is made for natural capital Thus, a seemingly growing national income is actually at the cost of a dwindling stock of natural resource assets, taking an economy towards an external situation of crisis.

A large body of literature points towards the limitations of the GNP concept, one of the

variants of the national income aggregates There has been an increasing criticism of this conventional measure of national product on the grounds that it is a poor measure of 'welfare' in some sense.

The conventional SNA record man-made assets - such as plant and machinery, buildings etc. as productive capital, which are written off against the value of production as capital depreciate on a year to year basis This practice ensures that a part of the capital that gets used up in the course of production has provision for its replacement in the form of accumulating depreciation allowance However, as natural resources are not so valued, neither their loss entails a negative charge against the current income nor do their consumption depict their declining future production potential The fundamental principle that gets flouted in the above analytical framework is non separation of income from capital.

Resource Depletion

At the time of formulation of SNA, the natural resources were abundant and their possible scarcity never figured in the National Accounts Development was visualized as a direct shoot-off o savings and investment in physical capital Whereas provisions were made in the form of depreciation to assure their replacements, no provisions were made for natural resources for the simple reason that they entailed as investment costs in the form of their being manufactured (produced) Hence, whereas the depreciation or replacement of the tools and equipments infrastructure etc required for extraction of say minerals figured in the national accounts, the decline in rate or value of the resource being extracted never found its place in the NIA The difference in the treatment of natural resources and other assets provides false signals to policy makers It confuses the depletion of valuable assets with the generation o income The results can be illusory gains in income and permanent losses in wealth

The case becomes critical in resource dependent economics In these countries, the revenues derived from these resources, finance investments in industrial capacity, infrastructure education etc While national accounts would shown an increase in income and investment,

nowhere would be the loss of valuable asset reflected. The extreme repercussions could be

* Miscalculation of the development potential
* Illusory spending limit of the government because of miscalculated national income.
* Non sustainability of resource dependent economics.

The case becomes even more critical if the resource proceeds are used to finance current consumption in which case the economic path becomes unsustainable ultimately

Environmental Degradation

All economic activities have some impact on physical environment. When the pressure was small, the environment was safely assumed as a sink to receive the residues of the production and consumption process and their side effects were considered as 'External Effects', for the simple reason that the costs of environmental degradation are not being borne by the economic actors who cause them

However, the effects of environmental resource depletion cannot be outside the profit and loss account of the society It is essential to properly attribute costs and benefits and to clearly distinguish between true income generation and drawing down capital assets by resource depletion or degradation.

National Resource Accounting

All these issues presented till now show that the current system of national income accounting is not adequate for resource dependent economics It then becomes imperative to develop a framework that overcomes these anomalies and presents a true picture of the national economy Natural resource accounting, is such a framework that attempts to provide a systematic and formal methodology for discussing the nation's stocks and flows of environmental assets and liabilities in the form of environmental deterioration.

Recent developments in resource accounting

There have been several attempts at resource accounting, with variations in focus and scope. These can be classified into four groups The first is limited to identification of pollution - abatement and other environmental expenditures. The second focusses on measuring changes in stocks of resources using physical units of measure The third focuses on modifying GNP and NNP by subtracting out the value of resource depletion and the fourth attempts a comprehensive resource and environmental accounting both in physical and monetary terms

Environmental accounting in development policy : The French experience

In an attempt to incorporated environmental concerns in the national income accounts France has established the "natural patrimony accounts", which are quite similar to the Norwegian "resource accounts" The information currently available on the environment in France is formally organized into a hierarchical system that comprises six levels

- level I for heterogeneous data specific to the environmental field or socioeconomic data
- level II for composite yet sectoral statistics on water, atmosphere, land, noise
- level III for comprehensive studies published periodically or compiled form a wide range of sources national and regional
- level IV for actual environmental accounting - patrimony accounts and satellite accounts
- level V includes two models, the first assesses the effect of environmental policies on production, prices, foreign trade and the second estimates pollution or resource extraction linked to various development strategies

The Norwegian experiment

Developing as well as developed countries are under severe environmental stress Norway was among the first countries to establish a separate body to address the environmental problems of the country with the establishment of the ministry of environment in 1972 Realizing that the ministry needed data and information to arrive at suitable policies and

decisions, there was an urgent need for an accounting system that would supplement the conventional accounts with information on environment and the natural resource base so that resource and environmental considerations could be effectively integrated into traditional economic and social planning

Some considerations were arrived at for developing pilot resource accounts in Norway for selected natural resources which are as follows .

- the resource selected should be economically or politically important,
- primary statistics for the resources should be available or possible to establish at reasonable costs,
- accounts should be compiled for several different resources,
- definitions of sectors and commodities in the resource accounts should, if possible, follow the definitions of the national accounts.

Norwegian material accounts cover hydro power, minerals like coal, oil, gas, iron, titanium, copper, zinc, lead, pyrite, sand gravel and stone, and biotic resources like fish and forests Energy accounts, in which levels of production and conversion and net output of primary energy are compiled, constitute an important component of material accounts Energy accounts also take into account data on international trade in energy commodities and changes in inventories Since minerals like iron, titanium, copper lead etc , are of no great economic significance in Norway, only the reserve part of mineral accounts are updated annually Forest accounts follow the same principles as energy accounts, but the two are different in that

- forests provide inputs to very few Norwegian production sectors, and
- forests, unlike energy resources, are biotic and renewable, and so reserve and extraction are more important in forest accounts

Forest accounts and energy accounts are closely related because wood from forests is either transformed into other products or used as energy.

Resource accounts have also been developed for fish which are an important natural

resource for the Norwegian economy.

Thus material resource accounts for Norway come under four main heads : energy, minerals, forests and fish Though the structure for all material resource accounting is the same, there are considerable variations among the different classes because the resources vary in degree of renewability and mobility as well as in their role in trade as well as the number of user sectors

Environmental accounts record in a systematic manner the state of various environmental resources like air, water and land Two main problems associated with environmental accounts relate to the definition of the state of the resources and the variation of the usefulness with spatial disaggregation

Environmental accounts in Norway now comprise accounts for land use and emissions to air at various sectoral and regional levels and some ad hoc studies of solid and hazardous waste, radiation and noise

Land use accounts provide data on the availability and changes in availability of land of various quality classes, suitable for different land uses To cope with the problem of paucity of data, three registers have been established Two geocoded registers documenting the land use and the quality of land, one for rural and the other for urban regions The third register contains information on existing plans for land use in the municipalities of Norway

The environmental accounts for air partly report on indicators for the quality of air and partly on emission levels of various polluting elements based on deduced information from energy use and industrial statistics

Need for a Special Approach to NRA for India

Even if a well-developed framework for NRA were to be available, we would want to examine it for its appropriateness to India Ours is -

- a large, populous, poor country that needs economic development,
- a country where agriculture is dominant,

- a country in which much economic activity is in small and informal marketing sector,
- a country in which hundreds of millions of poor depend on natural resources or their subsistence,
- a country where bio-mass dependence is high for energy needs in rural and urban areas;
- livestock population,
- a country with a large cultural diversity,
- a country with a large ecological diversity,
- a country whose traditions recognize and respect rights of non-human beings
- a country which has still preserved many of its virgin forests and biodiversity,
- Because of non monetization of these resources Their exploitation would further increase with the international market being opened for transactions of not only manufactured goods but also the gene pool wealth with the resource rich countries, India being one of them.

The framework hence would have to take into account all these factors.

Conclusion

From the above discussion it is obvious that the current national accounting system has several limitations including non-measurement of by-products of economic activity such as pollutants, depreciation of environmental assets and natural resources, environmental liabilities such as chemical dumps Several attempts have been made and are currently underway to address these issues However, these are piecemeal approaches, heavily biased at arriving at one single "correct" number

As Kuk Hamilton has suggested, with sustainability becoming a policy goal, it is essential to develop new "forward looking" indications to measure net investment or national wealth

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WORKING PAPER SERIES

ENVIRONMENTAL IMPACTS OF PROJECTS: PLANNING AND POLICY ISSUES

by

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Gopal K. Kadekodi
and
Nandita Mongia

July 1993

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Institute of Economic Growth,
Delhi

July 1993

Preface

This report is the second part of a major study on <u>National Parameters for Project Planning in India</u>, carried out at our Institute. The first part has already been released under the title National Parameters for Project Appraisal in India as an IEG working Paper No E/152/92, January 1992

In this study a new and emerging dimension of project planning and appraisal methodology has been focused. The development projects often involve use and abuse of natural resources. Use of them for development activities will mean loss of their preservation values Abuse, ofcourse, leads to externality problems Both preservation and externality losses are automatically accountable in perfect market economy. But, in the absence of it, the planning methods or 'inventions' will have to account for them through indirect valuations (i.e. shadow pricing) or control regimes (i.e setting standards or policing) or through fiscal instruments. A second problem associated with natural resources is the issue of crowding and 'tragedy of the commons'.

In this monograph, attempts are made to address to these problems from the viewpoint of project planning

We are thankful to the Planning Commission for having suggested us to undertake this study and also funding it partially In particular, we wish to express our gratitude to Dr. U K. Kohli, Advisor planning commission for all the assistance provided Ms Poonam Bansal and Mrs Shashi Agarwal handled the statistical and computer programming tasks We are grateful to them The entire manuscript was processed in the Computer Unit of the Institute We are thankful to Shri K Lal and his collegues for the help in this respect

Discussions with a number of collegues and experts made our study more purposive We are thankful to Dr. M N Murty and Prof. S.N Mishra. All errors and omissions, of course , are of our responsibility.

Kanchan Chopra
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July 1993

Glossary of Abbreviations

AC = Per hectare cost of Technology for abatement of waterlogging and salinity
BC ratio = Benefit/cost ratio
BOD = Biological oxygen demand
CA = Catchment Area per hectare of Irrigation Potential Created
CB = Cost benefit
CBIP= Central Board of Irrigation and Power
CFM = Cubic feet per minute
COD = Chemical oxygen demand
CVM = Contingent valuation method
EC = Environmental cost per hectare of Irrigation Potential Created
FL = Forest hectares submerged or lost as fraction of catchment area
MEB = Marginal environmental benefit
MEC = Marginal environmental cost
NB = Net benefit
NPV = Net present value
PPP = Polluter pay principle
VFL = Value of a hectare of forest land
WLA = Water-logged area as percentage of irrigation potential created

Table of Contents

PART A : FRAMEWORK OF ANALYSIS

1. INTRODUCTION

The process of development, in particular industrialisation has often been responsible for some major sources of environmental pollution and degradation. Not all industries pollute alike Pollution is related to the state of industrial technology and process combinations in use and management of natural resources. Certain industrial inputs inherently carry in them toxic chemicals, gases, trace gases and other particulates that stay in the atmosphere or water and pollute the eco-system. Their gestation period varies widely (from 10 to 12 years for methane to about 100 years for $Co2$), so does their impact on ecology Pollution concentration in the environment have damaging effects on living organisms and humans through air, water and soil pollution.

Environmental degradation can occur basically either due to consequences of industrial and natural resource related projects or neglect or misuse of natural resources (eg, tragedy of commons) The type of natural resource involved and the type of property rights institutions prevailing can lead to different types of externalities. The implication of these degradations (externalities) are also different for the present and future generations. Thus, there are four different combinations of environmental impacts that are relevant in the context of development planning as illustrated in the table below.

Examples of Environmental Impacts

	Nature of Projects	
Nature of env. impacts	Industrial projects based on natural and exhaustible resources	Use of natural resources without properly defined property rights
Affecting present generation	Use of fossil fuels & chemicals, polluting air, water; noise pollution and other health hazards etc	Over-exploitation of forests, top soil, water and other resources, leading to dry lands, deserts, wasteland etc.
Affecting future generation	Use of fossil fuels not making future generations forced to opt for nuclear options	Loss of bio-diversity and extinction of certain species and consequent effects on the eco-system.

In this context, all environmental resources can be said to have either developmental or preservational or both uses. The choice between these two broad categories of alternatives can be made by taking account of inter-temporal use as well as substitution possibilities Project planning taking such environmental impacts into considerations assumes therefore, some special importance. Furthermore, corrections to environmental mismanagement tnrough fiscal and monetary instruments and incentives can also become relevant in many situations.

In so far as the producer alone is responsible for any pollution, the question of pollution abatement can be optimally resolved by making him responsible for controlling pollution to below tolerance levels In this sense, environmental management can become part of project planning. Alternatively, taxing the producer or creating incentives to the producer or receiver of the pollution can become useful price policy instruments. Finally, creation of alternative property rights systems such as people's participation, and charging the present users of environmental resources for reducing the share of such resources for the future generation (through proper shadow pricing such as water) etc., are some of the sectoral policy and institutional reform options

Part A of the study concentrates on methodology. Section 2 goes into such methodological issues in the framework of project planning. Section 3 deals with fiscal methods and imposition of environmental standards. Section 4 deals with a mix of other alternative strategies.

Part B of the report presents five different case studies covering exhaustible resource use, pollution, common property and natural resource related environmental problems. Coal mining and power sectors are selected as examples of important industrial and infra-structural projects with significant environmental effects. Problems of urban garbage disposal and water pollution emanating from urbanisation and industrialisation respectively are studied. Issues relating to the costs of maintaining natural capital (such as forest land) intact form the focus of the case study on river valley projects. Part C summarises the findings with planning and policy recommendations. Annex 1 lists the major pollutants. Major industries and project activities that pollute are shown in Annex 2. Safe limits of pollution hazards are listed in Annex 3 and 4.

2. ENVIRONMENTAL MANAGEMENT STRATEGIES AND METHODS

In the process of economic development environmental resources are affected by externalities or depletion due to development programs. Economic literature on pollution control typically treats the problem as a production externality which the market mechanism fails to correct. Often, because of the public good nature of the product being damaged, over exploitation and excessive damage are most common outcomes. The argument goes one step further to assert that market failure may be compounded by 'government failure' through wrong action and for inaction The property rights approach to pollution control desists increased government responsibility in the management of natural resources The public sector, it argues, provides no incentives for decision making authorities like bureaucrats and politicians to resist pressure groups interested in projects that may not be ecologically sound[1]. However, there are obvious limitations to the use of this approach in developing economies particularly where well defined and transferable property rights do not exist Also 'The polluter pays the polluted' principle can only work when both parties are equally strong to enforce a bargained and agreed upon deal [2] These are not found to be so in the context of developing economies and therefore not discussed any further.

Most policy makers have agreed upon the inevitable phenomenon of facing some environmental pollution as a concomitant of economic growth and industrialisation process. The disagreement is over the tolerable or admissible pollution

level that is to be allowed in an economic system and the definition of its level itself Reducing the pollution level to zero is not a practical policy option. However, pollution levels have been brought down substantially in many developed and some developing economies by government regulatory agencies and\or through incentives and instruments. A combination of fiscal instruments and project planning devices have had direct bearing on technology selection which has encouraged pollution abatement strategies The following section gives an over view of control strategies available to a policy maker.

2.1 Project planning strategies with economic evaluation of environmental impact

Pollution control at the project design and appraisal stage is different from other abatement strategies in that it takes preemptive measures at the design stage itself to minimise environmental damage instead of searching for direct control mechanism through standards or fiscal or monetary instruments after the damage taken place. It involves micro-level planning after detailed environmental assessment of a project has been undertaken in view of broad national objectives of meeting pollution standards This in turn calls for additional investments on pollution and hazard abatement techniques, mechanisms and systems Many approaches are currently in use for economic evaluation of environmental impacts, alternative abatement techniques and their costs. The choice between them is guided by the specific nature of a project and hence the specific environmental impact expected from it. The primary purpose of all these approaches is to arrive at a monetary measure of

tangible and intangible benefits and costs of abating environmental impacts to the levels of standards. Alternatively, when the environmental damage caused by a project may be viewed as a deterioration of natural capital, be it land, water or air, the cost of environmental preservation can be viewed as the cost of maintaining natural resources intact.

Environmental impact assessment approach and benefit-cost analysis have been often used together to guide the selection of investment projects An exante environmental assessment statement of a development project is useful as a primary input for benefit cost (CB) analysis Any tangible deterioration, depletion, enhancement or restoration of natural and environmental resources due to a project can be identified primarily through an environmental assessment statement accompanying a project proposal The CB analysis is then used to put a valuation on the benefit and damage (i.e cost) due to the project. Many of the gains from environmental development or preservation policy do not show up in the form of immediate monetary gain and are not recorded in the usual calculation of market based benefit/cost (BC) ratio. However the basic principles of BC ratio can be extended to incorporate some of these effects for project appraisal. This brings up the issue of evaluating non-tangible costs and benefits. Which environmental or resource impacts are to be included (i.e. boundary analysis related to the selection of time horizon) and how to quantify and monetize them is the crux of the problem.

Basic to environmental accounting in project planning is the valuation of environmental changes, gains and losses. In

the framework of UNIDO literature on project evaluation, such an accounting can be incorporated under a 'with and without' project analysis Furthermore, it is the consumers' willingness to pay as reflected in consumer surplus under a demand pattern which is to be accounted. Various methods developed and demonstrated in this study are based on variants of such a methodology

In addition to willingness to pay for the current use or loss of environmental resources or services, such resources qualify for postponing the decision on it to the future. In this context, three different values can be identified. The concept of 'existence value' is often used to capture the intrinsic worth of the environmental resource Rather, it is a value on the knowledge that a natural resource can be preserved 'Bequest value' is the second concept which accounts for the satisfaction one can derive from endowing future generations with a natural environment The third concept of 'option value' accounts for willingness to pay for the opportunity to choose from among competing alternative uses in the future However, on practical grounds, all these three valuations are quite difficult to assess The main reasons are (a) society may not assign unique values or any of them (b) in a way, all these values are not independent (c) there is an element of uncertainty of the future. Therefore, in this study, no specific attempt is made to arrive at these values, costs or benefits.

In the following sections some of the valuation methodologies with easy application are discussed. Sections 2.1.1 and 2.1.2 discuss the use of market prices in the evaluation process. In sections 2.1.3 and 2.1.4 methods using

surrogate market prices and pricing through 'artificial' markets are discussed.

2.1.1 **Valuation of benefit through use of market prices:**

(i) **Change in productivity approach**: In this approach the planner looks for valuation through impacts that result in productivity changes. These then can be valued using a 'with and without' project context. Both onsite and offsite project impacts can be included in this Depending on the proportion of the project's share in the total available product, the small project assumption may be used in analysing the role of market price in this analysis

Empirical studies have used the productivity change approach of economic valuation in numerous circumstances Forest and agricultural land productivity change or productivity changes of fishery have often been found to be results of environmental effects of a project[3]. Soil erosion and siltation condition of land are often altered by a project which inturn affect land productivity. Infrastructural development projects like road developments lead to soil erosion and loss of property due to land slides. In several African countries livestock grazing projects have led to overgrazing of forest areas affecting the bio-diversity and balance in the natural system. Ranching projects in Latin American countries have had similar effects. Valuation technique based on productivity changes, with and without the project have been applied to all such cases to evaluate the social cost of productivity change and compare the net benefit streams Standard benefit-cost approach of project evaluation would not have included these changes in its calculations.

As an example of measuring environmental costs of altering natural systems, section 9 of this report extends this approach It sets up a valuation procedure for major irrigation projects affecting command and catchment areas including agricultural and forest land It identifies four components of cost and or benefits to the society that need valuation and develops a procedure to identify and quantity each of these components.

(ii) <u>Loss of Earnings Approach</u> This method looks for symmetry in benefit and cost. A benefit foregone due to setting up of a project is a cost and vice verse. An example of this is the measure of loss of earnings (say wages) due to adverse environmental impacts on health and human morbidity to approximate benefit foregone Medical costs due to changes in environmental quality could also be added to this market price of labour (i e wages, to value the potential income loss and hence loss of value added contribution of individuals to the society.

Monetary expenses borne by the society due to ill effects of environmental changes have been used in empirical estimates to arrive at the environmental cost of a project. Pollution due to ambient air quality or exposure to toxic emission during working of a project life may lead to physiological plus biochemical and histological changes in humans through organ toxicity and lead to increased morbidity and mortality. Market wage rate may only partially reflect such 'non marketed' costs Economic cost calculations in such cases put a value on partial or total loss of individual's work and

earnings capacity. Coal miners faced with the black lung disease and their loss of earnings capacity is an example in view. Empirical studies involving economic costing of mining projects use medical expenses and foregone earnings to calculate the present value of future stream of earnings from such an activity. Ridker's (1967) study was the first ever analysis that used the human capital degradation to measure economic cost of a project. It calculated the cost of premature death and medical treatment and added it to the project cost. Larve and Seskin (1977), Schwing et al (1980) have indicated the process of obtaining damage functions linking air quality to health damages. More recently Dickie and Gerkins (1989) demonstrated reduced morbidity from air pollution control and the costs there of. In all such cases, the investment cost of pollution control and abatement techniques is to be weighed against the net change in the earnings etc. In Section 5, a case study on coal mining illustrates the methodology to identify health and stress costs of mining workers.

(iii) **Opportunity Cost Approach**: This is an evaluation approach similar to the loss of earnings approach. It is appropriate for evaluating unpriced, unmarketed resources. This method measures what is to be given up for the sake of preservation. Either of the following two methods of evaluation may be used to measure the opportunity cost of a project.

(a) The preservation versus developmental use of an environmental resource may be calculated to reflect the opportunity cost of a project. The net present value (NPV) of benefits expected to accrue from the preservation of a resource

may be compared to the NPV of benefits expected if it were to be put to developmental usage[4]. Since benefits from a natural preserve are known to grow overtime, their present value calculation involves a premium. On the other hand, the stream of benefits accruing from an alternate developmental usage is expected to decline over the life of a project. The corresponding NPV calculations involve a discount on this account Equations (1) and (2) define the present value of developmental and preservation benefits using both the discount and premium factors The present value of developmental benefits assuming a declining rate over time is defined as,

$$\sum_{t=1}^{T} \frac{bo/(1+\pi)^t}{(1+i)^t} \qquad \text{-----------------------(1)}$$

where,

bo = initial year's developmental benefits

T = the relevant terminal year for the development alternative

π = the simplified representation of the technical change adjusted for development benefits.

i = the discount rate

The present value of preservation option is written as,

$$\sum_{t=1}^{T'} \frac{bp\,(1+\alpha_t)^t}{(1+i)^t} \qquad \text{----(2)}$$

where α_t = rate of growth of annual preservation benefit.

bp = initial year's benefits from preservation.

T' = terminal year of preservation alternative.

Given the above relationships Krutilla et al (1972) estimated how much the preservation benefit would have to be to equal the present value of developmental alternative. Given bo,

and i, the minimum initial year's benefit (bpm) that is required to make the present value of benefits from preservation equivalent to the present value of benefits from developmental usage (bo), can be written as follows

$$\mathrm{bpm} = \sum_{t=1}^{T} \frac{bo/(1+\pi)^t}{(1+i)^t} \; , \; \sum_{t=1}^{T'} \frac{\mathrm{Rel}\ (1+\alpha_r)^t}{(1+i)^t} \qquad \text{--- (3)}$$

Given equation (3), even if initial years' developmental benefits are large, the preservation benefits in comparison need to be only modest, for the latter to have a high present value Given an estimate of developmental benefits the corresponding present value of a rupee worth of initial years' preservation benefits can be computed using equation (3) In an empirical application of this theoretical formulation Krutilla et al demonstrated the preservation benefits of Hells Canyon in USA far out stripped the developmental benefits of setting up a hydro electric project at the canyon site Though a traditional benefit cost analysis favoured setting up the hydro project, using a discount rate on developmental benefits and a premium on preservation measures reversed the choice

Table 2.1 below shows the premium on account of preservation value to be charged to a developmental project which otherwise has a preservation value The premium measured as bpm/bo are estimated for values of π and α varying in different ranges. In absence of any benefit i.e., π=0 and α=1, the development benefits need no further adjustments. But, for any project having some preservation benefit, it should be added to the development benefits with a premium. The premium on account of this is shown in the table. For instance, α=0.05 and π=0.1,

every rupee of initial preservation benefit is equivalent to Rs.3.34 of development benefit. These premiums can be used to add preservation and development benefits.

Table 2.1: Preservation benefit in terms of development benefit

α/π	0	0.05	0.1	0.15
0	1.000000	1.462033	1.926701	2.391704
0.05	1.734581	2.536018	3.342023	4.164151
0.10	3.932735	5.749803	7.577193	9.406010
0.15	12.692450	18.556660	24 454660	30.356380

Note. 1. 50 years of project life assumed.
2 Social discount rate of 12% assumed

(b) An alternative method using the opportunity cost approach is to estimate the net additional cost of generating the same service from the next best alternative source. Rather than trying to put a value to the natural preserve in its current state, which is quite difficult and can become subjective, this approach measures the net additional cost of generating the same service from the next best alternative source Thus in the Krutilla-Fisher analysis the opportunity cost of preserving the Hells Canyon is the difference between the cost of hydro electric power generation at the canyon site and the next cheapest power source This analysis studied the two power sources with sensitivity on rates of technological progress and decided in favour of drawing electricity from the alternative considered to the Hells Canyon hydro electric project.

Both the opportunity cost measures discussed above are cost side approaches. However, they are generally used to measure benefits. This approach is a quick and powerful way of illustrating the real cost difference between two or more

alternative methods of meeting the same goal but have very different environmental impacts The case study in Section 7 illustrates the method for evaluating the benefits of gas generation from urban waste

2.1.2 <u>Valuation of costs through use of market prices :</u>

(i) <u>Cost effective Analysis :</u> Due to insufficient knowledge about the link between environment effects and the project design, benefits due to environmental protection and abatements may be difficult to estimate. In such a situation cost effective analysis can be used as an evaluation technique This approach uses market prices to evaluate alternate cost options of achieving a set of environmental targets It may also be used to evaluate alternate goals by comparing different costs of achieving them Alternatively, if the financial resources available to reach a pre-defined goal are fixed, cost effective analysis may be used to choose the least cost option. The options to be appraised may be limited by available technology and by fund availability The sensitivity of abatement costs to increasingly stringent standards of pollution control can act as a guide to the choice of cut off levels of abatement activities.

This approach characterises projects not by their net welfare impact but by the net costs of realising a specific goal. All other outputs are measured in terms of costs and benefits. These are then used to establish the ratios of levels of goal achievement over net cost. In an economic analysis of water pollution abatement for paper and pulp industry in India,

Murty and Dasgupta (1987) published in Murty (1988) used this approach to calculate the social cost of three abatement methods available to this industry Each option was a mix of available technological processes The cost items consisted of annualised capital costs and operating expenses In the annualised costing of capital expenses a social rate of discount (lower than the market rate) was used to arrive at the social cost of abatement. Similarly for costing of other inputs like labour etc., shadow wage rates(lower than market wage rates) were used Additional costs needed to reduce the pollution load through the introduction of a process or a process change were costed and weighed against the benefits that accrue subsequently during the project life The study covered the cost of abatement option available to both small and large paper mills

(ii) Preventive expenditure method: Individual economic agents like producers or consumers may protect themselves from environmental damage on a voluntary basis The defensive expenditures incurred by them can be used as a reflection of minimum value of benefits generated This expenditure may be actually incurred by them (e.g., cost borne out for sound insulation to cut out noise pollution) or it may be based on willingness to incur expenses on this count. When actual expenses are not incurred, willingness to pay is similar to contingent valuation approach and (discussed in Section 2.3). The preventive expenditure approach is also known as the 'mitigation expenditures' method. The demand for mitigating environmental damage is a demand for environmental protection. Theoretically, it is a downward sloping curve denoting an inverse

relationship between demand for exclusion facilities and its price. In the case study on urban waste disposal presented in Section 7 the cost of waste collection is treated as one such benefit.

(iii) Replacement cost approach The rationale for this approach is similar to that of preventive expenditure approach. It considers the costs incurred to replace productive assets which are damaged by a project to be the estimate of minimum benefits of protecting the environment. It is different from the preventive expenditure approach. In this approach the replacement costs are not based on the subjective valuation of an economic agent, but on actual costs to be incurred if damage has occurred To that extent it can be used to asses if it is more efficient to let a damage occur than repair it, or prevent it in the first place from occurring Examples of relevance are costs of replacing nutrients in soil, replacement cost of buildings and landscapes due to underground mining etc.

The assumptions implicit in the use of this approach is that the magnitude of damage is measurable and that it is economically efficient to make the replacement. If undertaken, it actually reveals a willingness to pay for environmental improvement An example of the use of the replacement cost technique is a study by Stocking (1986) that measured the value of nutrients lost from agricultural land in Zimbabwe. In another study Kim and Dixon (1986) followed a similar approach to examine the viability of two alternative soil stabilization techniques when the productive asset lost was soil in upland area, in Korea. The cost to be incurred to physically replace the lost soil and

nutrients was used as an estimate of value of the benefits of the reduction in soil erosion. This approach of course is a proxy method when more direct measures of loss of welfare are not available. A case study on coal mining presented in Section 5 illustrates the above two approaches.

(iv) Shadow project approach : This is a special type of replacement cost technique. Economic costs of lost benefits can be approximated by examining the costs of another project which would provide substitute environmental services The total cost of the substitute project is added to the resource cost of the original project to give an estimate of its full cost to the society. Including the shadow project cost to the original cost gives an indication of how large the benefits of the project have to be to outweigh the costs. The realisation of the tremendous cost involved in replacement would encourage policies that protect them in the first place. A varation of this approach was used by Chopra et al (1990) in evolving the benefits from prevention of soil erosion in the watershed upstreams of Chandigarh. The benefit was equated to the saving in cost of desilting the downstream lake by mechanical dredging.

2.1.3 Evaluation through the use of surrogate market prices :

In the absence of market prices to evaluate benefits and costs the choice of projects may be guided by implicit valuation of environmental factors. This can be undertaken by looking for an observable market price that reflects an unmarketed environmental impact. The valuation of a service or a good would then include the tangible cost of the product itself and a mark up or down due to the environmental factor.

Three alternative techniques or approaches are discussed below :

(i) <u>The property value or hedonic price approach</u>: Value of a fixed asset such as land or real estate often would reflect the utility stream consumers expect from it. Other things remaining the same, land values in a polluted area will be less than those in an environmentally preferred area. The difference between the two land prices would be an implicit price of their characteristics which consumers are prepared to pay for. The identification of property price effect can be done through multiple - regression analysis for either time series or cross section data The later is preferable and more suited to the purpose, because time series data show other influences that have worked over time, and may be difficult to identify or control.

If the environmentally preferred product is a public good and has a close substitute in the form of a private product (viz. private swimming pool vis-a-vis clean lakes or streams, clean drinking water from the municipal sources vis-a-vis private arrangements that ensure it) then the benefit from the increase in its supply may be deduced from the reduction in the purchase of the private good.

(ii) <u>Travel cost approach</u>: In case the environmental good being consumed is a recreational facility that visitors frequent, the surrogate price approach is similar to the evaluation technique known as the travel cost approach. The transactions price a visitor is prepared to pay for visiting a recreational site may not often be reflected by the nominal

entrance fee charged for it. The distance travelled to get to the service (eg., park) and the cost therein is a complete indication of the value of the recreational service to the visitor[5]. If an investment project along with its benefits and cost ends up providing for recreational facility (eg. a large dam and a lake) the valuation of benefit will require that the minimum environmental advantages are included through the travel cost approach.

(iii) Wage differential approach: This approach is based on the theoretical presumption that market for labour is competitive and labour enjoys free mobility in terms of choice of jobs, both qualitatively and geographically. Such characteristics of a labour market will ensure wage rates equalised to the marginal productivity of labour. To attract labour to jobs and locations with higher pollution risks involves payment of higher wage rates i.e. there is a 'price' at which labour is prepared to expose itself to increased risk or vice versa. Job amenities (or the lack of it) translated in terms of wage differentials can be explicitly used for evaluation purposes just as land price differentials are used as surrogate prices in the property value approach[6].

2.1.4 Valuation using artificial markets :

(i) Contingent valuation method: In the absence of conventional market data on prices on implicit markets, an approach generally referred to as contingent valuation method (CVM) has emerged in the literature. This is a survey based valuation technique which measures consumer's preferences in hypothetical situations. In this approach consumer's willingness

to pay either for an environmental asset or to avoid a certain hypothetical damage or accept compensation in case of damage is assessed through a survey. Though the orders of magnitude of the two measures are not expected to be identical (since accepted level of compensation for a loss is usually higher than the payment level to prevent the same), they indicate similar preference ordering.

In the case of a pure public good (i.e. marginal cost of providing it to an additional consumer is zero) available equally to all, individual willingness for payment (or acceptance of payments) are summed up to get a notion of aggregate valuation of an environmental asset. The individual payments levels may be got by a one-shot response to a bid offered in a survey questionnaire Alternatively, an iterative process of bidding game can be developed, to bring about final maximum or minimum level of acceptance by repeated sampling procedure[7]. In this converging bid approach, the first bid is an indication to the consumer of orders of magnitude involved in the deal. The level of the initial bid may lead to some biases in the response made Besides this starting point bias, this method has been criticised for the possibility of raising strategic biases (i.e. the free-rider problem) and/or hypothetical bias, because a consumer is not reacting under actual contingencies of a real life decision making process.

Inspite of these biases, this method is a good first approximation to the true preferences in a society. By indicating willingness to pay or willingness to accept compensation, this approach can be used to go beyond society's

evaluation of direct environmental benefits, that do not have conventional markets. This approach can be used to reflect society's premium on the existence of an environmental facility or a premium on the knowledge that options of using the natural resource exist. Some bidding games based on the CVM method may be used to evaluate society's premium on bequeath value of conserving resources for the future generation.

(ii) Trade-off games : As an extension of the bidding game approach this method can be used to determine individual's choice between various outcomes. Each outcome due to a project can have two components:-i) a certain sum of money to be paid (it may as well be zero), and ii) a certain amount of environmental good (bad) The value of money at which an individual is indifferent between two different environmental outcomes is the trade-off accepted by him for environmental damage (or conservation).

3. ABATEMENT STRATEGIES USING FISCAL DEVICES AND STANDARDS

Command and control strategies of pollution reduction is a method that has been adopted in various countries for pollution control. A combination of tax and subsidy measures which are regulatory in nature are imposed with certain objectives. These are inherently based on the notion of defining a social optimal level of pollution to be tolerated and regulated through a fiscal regime. The idea behind any fiscal measure and incentives is to reduce the environmental damage to a limit and not necessarily to aim at reducing it to zero. Assuming that the 'principle of polluter pays' is an implementable policy, it is possible to arrive at optimum tax and subsidy rates to manage the environmental degradation However, the fiscal method does not guarantee attaining environmental standards based on technical and consumers' tolerance evaluations. Therefore, both fiscal methods and setting standards may be necessary to arrive at the most acceptable policies.

The tax principle, first developed by A.C pigou accounts for pollution damage as a social cost and net benefit to the polluter as a private gain whose production activities lead to the pollution enternalities. Assuming that a polluter finds it worth paying any pollution tax upto a level when the marginal net benefit (profits) from production activities is greater than the marginal tax to be paid, the optimum pollution damage and the corresponding tax rate are derivable.[8] However, in practice, it will be extremely difficult to identify and estimate the marginal damage functions and hence to arrive at

precise optimum tax rates To the extent, the marginal gains from production activities are also difficult to identify and estimate, the tax principles are often misused and cuised.

An alternative to estimating (or obtaining information on) marginal net benefits from production activities is to estimate marginal abatement costs associated with different levels of pollution abatements. Then the optimal tax rate is set at the rate when marginal damage cost and marginal abatement cost are equal. Both these methods can yield to optimum levels of pollution management.

Alternatively the social optimum damages may be defined as an absolute maximum standard of acceptable pollution level arrived on the basis of health standards or any other standard, defined exogeneously[7] Acceptable environmental concentration for (i.e x micrograms per m^3, or levels of contamination in drinking water) are decided by competent authorities and entails setting up of regulatory monitoring agencies that have power to impose penalty in case of violation of standards. The setting of standards may further be complemented by a host of incentive policies, the like of which are listed in table 3.1.

Table 3.1

Typology of economic-incentive pollution control instruments.

Type of instrument	General description
Effluent charges	Paid on discharges into the environment and are based on the quantity and/or quality of the effluent.
Incentive effluent charges	Revenue collected via the charge is not returned to the polluter.

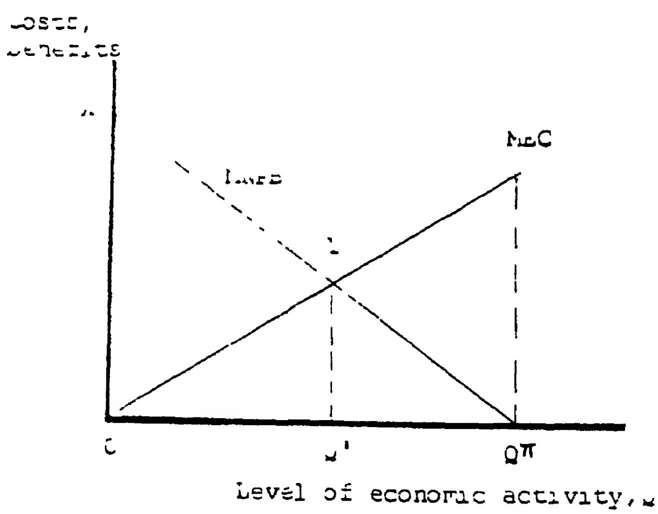
Distributive effluent	Revenue collected via the charge is charges which is returned to the polluter, in the form of subsidies for new pollution control equipment.
User charges	Payments for the cost of collective or public treatment of effluents.
Product charges/tax differentiation	Additions to the price of products, which are polluting or are difficult to dispose of, the former have a revenue-raising feature.
Administrative charges	Control and authorisation fees.
Subsidies/Grants	Non-repayable forms of financial assistance, contingent on the adoption of pollution abatement measures.
Soft loans	Loans linked to abatement measures and carrying below-market rates interest
Tax allowances	Allows accelerated depreciation, tax or charge exemptions or rebates if certain pollution abatement measures are adopted.
Deposit-refund system	Systems in which surcharges are laid on the price of potentially polluting; refund of the surcharge is given on the return of the the product or its residuals.
Market creation	Artificial markets in which actors can buy and sell 'rights' for actual or potential pollution.
Emissions trading (bubbles, offsets, netting and banking)	Within a plant, within a firm or among different firms.
Market intervention	Price intervention to stabilise markets, typically secondary materials (recycled) markets.
Liability insurance	Polluter liability leading to insurance market.

<u>Source</u> · Pearce & Turner (1990)

Some of the above options are based on the polluter-pays principle (PPP). For practical reasons the choice amongst these methods is often guided by revenue raising and bureaucratic compatibility criterion. Usually a combination of regulation and incentive instruments serve the objective of pollution control well, so long as maintaining economic efficiency is not a primary goal. A mix of 'standards' and tax policy will generally be preferable to the imposition of standards alone, unless the latter recommends outright prohibition In the case of outright prohibition, the marginal environmental cost (MEC) is vertical, reflecting infinite marginal damage cost. The effect of CFC in the atmospheric ozone layer and a global ban on it beyond the year 2000, is an example in view.

Often questions are raised regarding the need for tax and subsidy programmes when at the time of the project clearance itself sufficient investment allocations are made for pollution abatement, preservation and restoration of natural environment. There are both theoretical and practical reasons for having such schemes on top of accounting at project planning stage. First, at the time of project planning, identification of equilibrium marginal environmental benefits and marginal environmental costs may not be perfect Then specification of abatement investment may still remain subjective. Second, even if environmental control specifications are at the point of equilibrium, the actual operation of production process may not be at this optimum. Underproduction but meeting environmental standards may call for a subsidy and overproductions may attract taxes. Third, as and when better information and knowledge is available about

the hazardous effects of environmental pollution, their cost and benefit curves shift. This calls for adjustments and respecification of standards and norms Such changes in environmental norms may call for tax and subsidy programmes so as to implement them more effectively.



Economic Definition of Optimal Pollution

4. OTHER STRATEGIES

Pollution abatement policies can be adopted directly at the production level. Adoption of any of the following 4 options singly or collectivity can abate pollution to a considerable extent.

(1) The production level of goods and services that generate polluting agents during their production process can be reduced. This inturn will reduce pollution.

(2) If lowering of production is not an option, end of the channel pollution reduction technologies can be put up by the polluting firms. Expenditure on setting up of abatement plants like scrubbers in thermal power chimneys or water treatment plants in leather manufacturing industries can reduce the volume of effluents released into water and harmful emission in the air.

(3) A third option could be the adoption of technological processes which have lower pollution hazards to begin with.

(4) Altering parameters of project appraisal as a method for environmental management of projects has also been suggested. Since environmental considerations deal mainly with the issues of maintaining resources intact for the future, it has been suggested that lower social rates of discount be used when evaluating projects that are likely to have an impact on the environment.

While the first option is a near non-starter, for developing economies the second and specially the third option have been accepted widely as method of costing of projects to meet pollution standards.

The abatement cost in the second option is based on

purely technological requirements. It is based on the cost of operating pollution control equipment and the costs of process changes wherever necessary[9] The third option involves engineering as well as technological breakthrough for introducing fuel switching technologies and needs to be costed accordingly. (eg. the R&D as well as technology adaptation cost of switching to solar cookers from kerosene based cookers, or moving to hydro or nuclear sources of power vis-a-vis thermal power)

A large and growing literature now exists around the issue of the links between social rate of discount, environmental management of projects and development The starting point essentially is the contention that using a lower rate of discount would imply a lesser weight on the present relative to the future and would help in preserving resources for the future rather than using them in the present. Before evaluating this argument, let us recapitulate that the social rate of discount attempts to measure the rate at which social welfare or utility of consumption falls over time It can be expressed as[10]:

$$r = ng + z$$

where r = social rate of discount

z = pure rate of time preference

g = rate of growth of real consumption per capita

and n = elasticity of the social marginal utility of consumption

The value of r recommended for India is 12%. This is less than the private opportunity cost of capital (R) which is 18.5% (as estimated in Murty et al 1992). Together, the two parameters determine the shadow price of capital and the allocation of

capital between different projects. In a perfect market situation countries with optimal levels of saving, the two tend to be equal and a lower social rate of discount would mean a higher level of investment. In the context of developing economies with suboptimal levels of savings, the capital-intensity of projects and therefore, the total level of investment (I) are determined jointly by the shadow price of capital and the social rate of discount. In a simplistic model of zero reinvestment benefits, the shadow price of investment (SP), is the ratio of the private opportunity cost of capital (R), i e , the rate of return on alternative investments to the social rate of discount (r) In other words the following set of equations determines the three variables

$$I = f\ (r,\ SP)$$

$$SP = R/r$$

and hence $I = f\ (r,\ R/r)$

Any change in r will therefore change I, the level of investment in the economy and affect the demand of natural resources required as 'throughput' for this investment Further, the effect is not unidirectional and cannot be predicted a priori We shall maintain in this study that on balance, it is better not to attempt environmental management of individual projects with a lower social discount rate for project evaluations. As can be seen from the equations above, such a procedure would influence the allocation of scarce capital across the board and would further require distinguishing between projects that affect the environment and those that do not do so In view of economy-wide linkages between production and environment, this would become

a very difficult proposition As an alternative, a combination of the conceptual approaches given above which amount to altering schemes of benefits and costs accruing from individual projects to correct for environment friendliness or otherwise of the project shall be adopted. The environmental cost of using certain technologies or undertaking specific projects is estimated using concepts of opportunity cost or cost of alternative technologies This approach is demonstrated for mining, power, urban garbage disposal projects, industrial projects polluting water and projects altering natural system (such as river valley development projects)

It is maintained that considerations of irreversibility can also be taken care of by altering streams of benefits from preservation and development Assuming that all natural resources have some preservation value in a finite time horizon but will have developmental value in infinite time horizon planning, the irreversibility cost can be accounted by comparing the current rate of using the natural resource versus its infinite time use EL Sarafy (1988) proposed a method to estimate the premium to be charged on developmental use of natural resources so as to arrive at its estimate of preservation losses This method is illustrated in the case study on coal mining in Section 5

Meanwhile, the limits of cost-benefit analysis as a guide to environmental policy must be acknowledged (Pearce; 1976). These limits arise out of the basic theorem that conventional externality correction will not prevent a dynamic process of increasing ecological instability from taking its course If indeed the environmental damage function is a

discontinuous one with costs going up to infinity beyond a certain level of production then the only strategy available may be the reduction of production levels of goods and services. Project appraisal is tenable as a means of environmental management only as long as that point discontinuity on the environment damage function has not been reached There is reason to believe that this is, by and large, true for developing countries.

A more holistic approach to the costing of environmental damage requires understanding of various linkages in the environment and economic/system Opting for either of the two methods discussed above would bring in a series of repercussions on the rest of the economy through changes in relative prices, production structure and trading behaviour of a country. An economy-wide linkage model can be worked so as to minimise the cost of pollution control when synergescis of the adjustment mechanism is adequately represented. It has been demonstrated in empirical exercises that these adjustment processes may mean a large reduction in the relevant cost of pollution control[1] This framework is flexible enough to accommodate a "green accounting" system where changes in national wealth or resources like stock of soil, coal reserves, forest reserves etc , can be accounted for This approach is most suited to the adoption of a sustainable development process. It involves a general equilibrium approach to the measurement of environmental pollution cost and is high time that countries like India adopts such an integrated production approach.

ANNEX 1

Some Major Pollutants

1. **Power Plants:**

Thermal power plants are known to discharge pollutants like fly ash, smoke, soot and gaseous oxides of sulphur, carbon and nitrogen. Fly ash contains toxic metals like zinc 6%, barium 12.0%, vanadium 0.08%, copper 1 3% etc Emissions of hydrocarbons can be reduced with the use of fuel oil or coal after gasification, instead of using only coal in the thermal power plants. Air pollution from natural gas boilers is another health hazard Such natural gas contains 80 to 90% of methane and unsaturated hydro-carbons Nuclear power generation, though a smokeless energy source, involves the discharge of radioactive effluents Potential human exposure is involved at all stages of the nuclear fuel cycle, including mining and milling of uranium, fuel fabrication, operation of reactors, reprocessing of fuels and transportation The ultimate disposal of radioactive wastes is engulfed with enormous problems. Hydroelectric power generation is so far, a safe source of electricity, if planned properly.

2. **Paper, Pulp and Newsprint Manufacturing Unit :**

Major pollutants are organic suspended matter and alkali arising from washing of the digested material, bleaching agents etc.

3. **Fertilizers :**

Oxides of sulphur, nitrogen, ammonia, hydrogen sulphide, chlorine , dust and suspended particles are major constituents of air pollution. Water is polluted by ammonia,

urea, arsenic, phosphates, fluoride and oil. Strong waste and sludge containing arsenic and packing materials comprise the major solid pollutants. Ammonia and Fluoride cause soil pollution when the liquid wastes are discharged on land. The hazardous wastes from nitrogen fertilizer units are mostly spent-catalysts and carbon sludge, contaminated with oil and naphtha. Wastes generated from **Vetrocoke process** are upto 2% urea and 0.5-1.0% ammonia which are carried away in the drains. Likewise 2-2.5% of phosphate and 0 7-0.8% of fluoride are carried in waste waters

4. **Leather Processing and Finishing Industry:**

Discharge of lime solutions, spent tanning liquors, colours, phenols, chromium etc , can pollute the water sources giving rise to problems of taste, odour, elurbidity, ,metal toxicity bioaccumulation in fish and crops etc

5. **Textile Industry:**

Waste waters from yarn spinning and clothing wearing contains particulate and starch Waste water from dyeing, printing and processing of cloth contains effluents like dyestuffs, crome dyes, caustic liquors and various chemicals In case of synthetics also, various chemicals are mixed in the effluents, such as phenols, benzene, toluene and solvents and hydrocarbons

6 **Chemical Industry:**

Wastes from chemical industry have high COD and BOD ratios Toxic fumes and soot emissions cause varying degrees of hazards Air pollution in chemical industries is especially caused when air itself is one of the process ingredients from

completion of reactions of synthetic gas, HCN, phthalic anybydride, carbon black etc. The effluents generated are characterised by the presence of organic substances which are not biodegradables. These are toxic substances, nitrogen compounds and heavy metals.

7. __Cement__

Sources of emission of particulate are rotary kilns (dry, wet and semi-dry) saw mill, clinker cooler, finish grinding, packaging and storage Emission also arises from pulverisation of coal

8. __Iron and Steel Plants__:

Main source of pollution are sintering, coke ovens blast furnace, steel making, captive power plant and coal handling operations From sintering plant, dust emission to the extent of 2 5% of the product is expected to emerge In the coke oven, about 60% of the total coke plant particulate emissions arise by coke oven charging and about 30% by discharging. The top gas from the furnace containing significant concentration of particulate, after necessary cleaning, is used as a source of the energy in the steel plants

The emissions will be normally high during oxygen lancing; they will contain iron particles and will have high temperature. In view of this, high energy venturi scrubber or bag filter may be used as the control equipment ESP can also be used. In steel making, the following standards based on achievability have been prescribed by the Central Board :

(a) During Normal Operation - 150 mg/NM 3

(b) During oxygen Lancing - 400 mg/NM 3

ANNEX 2

List of Major Polluting Industries

1. Primary metallurgical producing industries - zinc, lead, copper, aluminium and steel.
2. Paper, pulp and newsprint
3. Pesticides/insecticides - chemical
4. Refineries
5. Fertilizers
6. Paints
7. Dyes
8. Leather tanning
9. Rayon
10. Sodium/potassium cynide
11. Basic drugs
12. Foundry
13. Storage batteries (lead acid type,
14. Acids/alkalies
15. Plastics
16. Rubber synthetics
17. Cement
18. Asbestos
19. Fermentation industry
20. Electroplating industry
21. Thermal Power Plants

List of projects altering Natural systems

1. Mining
2. River valley projects
3. Hydro power projects
4. Extraction of forest product projects
5. Monoculture and other interference with bio-diversity

ANNEX 3 Pollution Hazards of Various Gases

S No	Name of Gas	Chemical Formula	Common Properties	Specific gravity or vapor density (air 1)	Physiological effect	Maximum Safe Exposure Limit (%)		Explosive limit (percent)		Likely location of highest concentration	Most Common Sources
						60 Minutes	8 Hours	Lower	Upper		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1	Carbon dioxide	CO_2	Colourless, odourless, when breathed in large quantities may cause acid taste Non infla mmable	1 53	Cannot be endured at 10% for more than few minutes, even if subject is at rest and oxygen content is normal Acts on respiratory nerves	4 0 10 60	0 5			At bottom, when heated, may stratify at points above bottom	Products of combu stion sewer gas Also issued from carbonaceous strata
2	Carbon monoxide	CO	Colourless, odourless tasteless, inflammable, poisonous, non irritating in 30 minutes at 0 2 to 0 25%	0 97	Combines with haemoglobin of blood Headache in few hours at 0 02% unconsciousness fatal in 4 hours at 0 1%	0 04	0 005	12 5	74 0	Near top, espec- ially, if pre sent with illuminating gas	Manufactured fuel gas fuel gas products,co mbusion products of motor exhausts, fires of almost any kind
3	Chlorine	Cl_2	Yellowish green colour choking odour, detectable in very low concentrations non inflammable	2 49	Irritates respiratory tracts kills most animals in very short time at 0 1%	0 0004	0 0001			At bottom	Chlorine cylinder and feed line leaks
4	Gasoline	C_8H_{12} to C_9H_{20}	Colourless, odour noticeable at 0 03% inflammable	3 0 to 4 0	Anaesthetic effects when inhaled, rapidly fatal at 2 4% dangerous for short exposure at 1 1 to 2 2%	0 4	0 1	1 3	6 0	At bottom	Service Stations garages, storage
5	Hydrogen	H_2	Colourless, odourless, tasteless, inflammable	0 07	Acts mechanically to deprive tissues of oxygen, does not support life			4 0	74 0	At top	Manufactures fuel gas sludge
6	Hydrogen Sulphide	H_2S	Rotten egg odour in small concentration, odour not evident at high con centrations, colourless, inflammable	1 19	Exposure for 2 to 15 minutes at 0 01% impairs sense of smell, exposure to 0 07 to 0 1% rapidly causes acute poisoning Paralyses respiratory centre, death in few minutes at 0 2%	0 02	0 001	4 3	46 0	Near bottom but may be above bottom if air is heated and highly humid	Coal gas, petroleum sewer gas, fumes from blasting, sludge gas

7	Methane	CH_4	Colourless, odourless, tasteless, highly inflam mable non poisonous	0 55	Acts mechanically to deprive tissues of oxygen does not support life	Probably no limit provided oxygen %age is sufficient for life	1 0	5 0	15 0	Normally at top extending to a certain depth	Natural gas, sludge gas manufactured fuel gas, sewer gas, in swamps or marshes
8	Nitrogen	N_2	Colourless, tasteless non-flammable Prin cipal constituent of air (about 79%)	0 97	Physiologically inert					Near top but may be found at bottom	Sewer gas, sludge gas also issues from some rock strata
9	Oxygen	O_2	Colourless, tasteless odourless supports combustion, non poisonous	1 11	Normal air contains 21% of oxygen man can tolerate down to 12% minimum safe limit 8 hours exposure 14 to 16 % Below 10 dangerous to life Below 5 to 7% probably fatal					Variable at different levels	Oxygen depletion from poor ventilation and absorption or chemical consumption of available oxygen
10	Sludge Gas	About 60% methane & 40 % carbon dioxide with small amounts of H_2, N_2, H_2S, O_2	May be practically odourless, colourless, inflammable	0 94	Will not support life	Would vary widely with composition		5 3	19 3	Near top of structure	From digestion of sludge in tanks

ANNEX 4

TOLERANCE LIMITS FOR INDUSTRIAL EFFLUENTS PRESCRIBED BY U.P. POLLUTION CONTROL BOARD

Characteristics	Tolerance Limits for Industrial Effluents Discharged			
	Into Inland Surface Waters	Into Public Sewers	On Land for Irrigation	Into Marine Coastal Areas
1 Colour and odour				
2 Suspended solids, mg/1, Max	100	600	200	a) For process waste waters -100 b) For cooling water effluents -10 per cent above total suspended matter of influent cooling water
3 Particle size of suspended solids	Shall pass 850 micron IS Sieve			a) Floatable solids Max 3 mm
4 Dissolved solids (inorganic), mg /l, Max	2100	2100	2100	
5 pH value	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0
6 Temperature °C, max	Shall not exceed 40 in any section of the stream within 15 meters down-stream from the effluent outlet	40 at the point of discharge		45 at the point of discharge
7 Oil & grease mg/l, Max	10	2.	2.	20
8 Total residual chlorine, mg /l, Max	1			1
9 Ammoniacal Nitrogen (as N), mg /l	50	50	100	50
10 Total Kjeldahl nitrogen (as N), mg /l, max	100			100
11 Free ammonia (as NH_3), mg /l, Max	5			5
12 Biochemical oxygen demand (5 days at 20°C), Max	30	350	200	100
13 Biochemical oxygen demand, mg /l Max	250			250
14 Arsenic (as As), mg /l, max	0.2	0.2	0.5	0.[illegible]
15 Mercury (as Hg), mg /l, max	0.0[illegible]	0.0[illegible]	0.0[illegible]	0.0[illegible]

16	Lead (as Pb), mg /l, max	0.1	1.0		1.0
17	Cadmium (as Cd), mg /l, max	2.0	1.0	5.0	2.0
18	Hexavalent chromium (as Cr), mg /l, max	0.1	2.0	1.0	2.0
19	Total chromium (as Cr), mg /l, max	0.5	2.0	2.5	2.0
20	Copper (as Cu), mg /l, max	3.0	3.0	3.0	3.0
21	Zinc (as Zn) mg /l, max	5.0	15.0	10.0	15.0
22	Selenium (as Se) mg /l, max	0.05	0.05	0.1	0.05
23	Nickel (as Ni) mg /l max	3.0	3.0	3.0	5.0
24	Boron (as B) mg /l, max	2.0	2.0	2.0	
25	Percent Sodium, max		60	60	
26	Residual sodium carbonate mg /l, max			5.0	
27	Cyanide (as CN) mg /l max	0.2	2.0	0.5	0.2
28	Chloride (as Cl) mg /l, max	1000	1000	600	
29	Flouride (as F) mg /l max	2.0	15		15
30	Dissolved phosphates (as P) mg /l, max	5.0			
31	Sulphate (as SO_4) mg /l, max	1000	1000	1000	
32	Sulphide (as S) mg /l, max			-	5
33	Pesticides	Absent	Absent	Absent	Absent
34	Phenolic compounds (as C_6H_5OH), mg /l, max	1.0	5	-	5
35	Radioactive materials				
a)	Alpha emitters Mc/ml, Max	10^{-7}	10^{-7}	10^{-9}	10^{-7}
b)	Alpha emitters Mc/ml, Max	10^{-6}	10^{-6}	10^{-8}	10^{-6}

Source IS 2498 (Part 1) 1981

5. ENVIRONMENTAL ACCOUNTING IN COAL MINING PROJECT

5.1 Introduction[12]

The environmental effects from mining vary depending upon different mining techniques. In underground mining methods, exposure to methane, high percentages of coal dust particulate, temperature etc., lead to serious health hazards for mine workers Incidence of tuberculosis, black lung diseases and various skin diseases are quite common. In opencast mining, apart from health hazards due to coal dust etc., there are a number of environmental irreversible damages due to the involvement of land and water Such damages also exist in underground mining but on a much smaller scale as compared to opencast mining

The environmental management in coal mining generally will have to take into account of (i) water pollution, (ii) air pollution, (iii) land and forest reclamation and damages, (iv) noise pollution, (v) habitat rehabilitation and (vi) health hazards. Some of the irreversible implications of coal mining are loss of agriculture and livestock productions, fishing, forest based activities, and water and air quality contaminations. The land required for coal mining can come from agricultural, forest and other uses. On the basis of a sample of ongoing, sanctioned and future projects, the shares of agricultural and forest lands involved in India are estimated to be about 16% and 75% respectively, the rest being townships and government lands. In Raniganj coal field, the reclamation costs are estimated to range from Rs.20-40 lakhs per hectare. CMPDI has estimated for some pilot projects the reclamation costs as Rs.16-18 lakhs per hectare. In the USA, as a package for

environmental management, a range of 10-25% of total project cost is charged towards various components of abatement and reclamation. They also have a reclamation cess on coal produced from underground mines at 15 cents per tonne and from opencast mines at 35 cents per tonne The National Coal Board in England estimates the cost of restoration of mined land at 5% of total cost. Coal India had decided to provide Rs. 2.50 per tonne of coal produced as environmental protection costs, which is less than 1% of price of coal

5.2 Case Study of an Opencast Mine

5.2.1 Environmental impacts of opencast mining

The opencast mining involves, at first step, the removal of vegetable cover and the overburden to provide access to the coal seam. During actual mining - drilling, blasting and excavation are done which added to transportation generates lot of noise and dust and changes in water courses. The overburden is removed and dumped in the adjacent areas creating a different scene of the topography and even hydrological changes. Some of the major environmental changes are discussed below:

Land Degradation

The physical changes on land consists of breaking up of surface, topographical changes, subsistence, change in the composition and structure of top soil, sub-soil etc. Large quantities of soil get excavated, removed, transported and deposited to create a totally different type of topography. Changes in topography results in drastic change in drainage pattern and unaesthetic sight The structure of soil undergoes vast changes due to disturbed stability in terms of gravitation. Slope instability problem gives rise to land slides and rapid

soil erosion. Degradation of land causes siltation and degradation of surface water. It also leads to blanketing of top soil in the nearby agricultural and grazing land resulting in poor crop yields.

Hydrology and Water Pollution

Hydrological system involving both surface and groundwater regime undergoes significant changes because of coal mining activity. The direct impact is due to change in topography The modified topography alters the run off pattern, subsequently leading to inundation or water deficiency in some areas. Excavation and raising of overburden dumps impairs the natural drainage pattern to a large extent Cutting of large number of trees also changes the hydrological cycle of the area.

Mining activity often affects the groundwater hydrology subsequently Mining may expose permeable beds with artisan well condition Under these circumstances significant groundwater leakage takes place and the aquifer undergoes depletion thereby reducing the water table of the area. In many cases the recharge gets reduced due to stripping of permeable dumps. in such cases no or insignificant groundwater recharge takes place resulting in parching of good aquifires.

The main sources of liquid affluents from an opencast coal mine are. 1) dewatering of mine water , 2) Spent water from dust extraction and dust supressing system, 3) Leachate run-off from waste dumps. the water composition of mine water primarily depends upon the host rock composition. The spent water contains high amount of suspended solids which during run off causes substantial soil and other structural erosion. In some

cases the mine water can be of substantial quantity such as to pollute the surface water. The high suspended solids decrease the light penetration in water and hence affects the biotic life. Microscopic examination of coal mine water reveals the presence of parasitic protozoa and atrichous baci Vllus responsible for typhoid, dysentery, gastroenteritis, diarrhoea, skin infects etc.

Air Pollution

Atmospheric changes are caused by microclimatic changes. In opencast coal mine areas, these are in the form of air loaded with dust particles, high temperature caused by reduction in humidity in the air due to loss of vegetational cover, increase in the percentage of obnoxious gases like carbon monoxide, nitrous and certain other gases as a combined result of blasting, release of gases from vehicles, rocks, affluent etc. These pollutants not only affect the mine workers but depending upon the meteorological conditions affect the human settlements, agricultural land and livestock in the nearby areas

Impacts due to high levels of suspended particulate in air are: i) Respiratory ailments, ii) ophthalmic diseases, iii) lower agricultural yields, iv) lower consumption of fodder which affects the milk production, v) lower animal fertility and vi) poor visibility.

Noise Pollution

Mining operations such as drilling, blasting, loading and dumping generates significant noise especially in the work environment The sound levels in both audible and ultrasonic

range produced due to the above activities are known to have adverse effect on human beings and livestock Impact of various noise levels can be summarised as:

Noise Levels	Adverse Effects
20 - 50 dB	Speech impairment and annoyance
50 - 90 dB	Hearing impairment for 8 hour exposure
90 - 115 dB	Partial deafness and nervous irritability
> 115 dB	Permanent deafness
Impulsive noise (> 90 dB)	Frightens livestock grazing in the nearby areas

<u>**Vibration Problem**</u>

Blasting operations produce S, P and G waves of which S and P waves are short waves and get attenuated over a short distance, whereas G waves travel a much longer distance The intensity of these waves is felt maximum at the point of blast and decreases with distance The impacts of vibration produced by G wave are i) Accelerated landslides in hilly areas, ii) Destruction or weakening of structures, iii) Rattling and breaking of window panes, iv) Annoyance to human beings and livestock.

In summary, the major environmental effects of an opencast mining project are therefore (i) top-soil disturbance and hence land degradation leading to decline in agricultural productivity and loss of land (ii) disturbed water course leading to droughts and floods (iii) hydrological changes leading to deepening of groundwater tables and water pollution (iv) loss of aesthetic value (v) health effects of long lasting type and (vi) ground vibration and hence seismic changes. The

economic impacts are observable in migration and habitat displacement, unemployment and loss of security

The land use pattern before and after mining operations in a typical large opencast mine project differs significantly as shown below as an illustration.

Table 5.1: Land Use Pattern in an OC Mine Area

Pre-mining stage		Post-mining stage	
Agricultural land	18.3	Reclaimed land for vegetation	41 3
Homestead land	4.5	Agricultural land	11.3
Forest land	53.4	Residential area	22 7
Water courses	0.8	Industrial complex	12.8
Water land	22.8	Waste land	11.6
		Water body	0 3
Total	100.0	Total	100 0

Source Sridharan (1990)

The loss of agricultural and forest land converted into reclaimed land and waste land will amount to a net loss of agricultural and forest productivity. Some compensating gains are however, achievable by the industrial complexes. The land use plan after the mining operations and also concurrently will have to be carefully monitored to achieve the best returns with minimal environmental damages.

5.2.2 Direct Costs towards Environmental Management

The project authorities directly invest on pollution abatements to meet the environmental standards. They include installation of air, water and noise pollution control devices. A closed circuit water treatment with zero effluent, drainage of suspended solids, black topping of long-travel roads, water spraying, installation of dust collectors, setting up of green belts etc., are some of the major abatement measures. Other costs incurred by the project authorities are of the nature of

compensations for irreversibilities. The are towards land reclamation, forest restoration, rehabilitation and providing security and townships.

The cost of pollution abatement and environmental restoration taken from a large opencast mine project are summarised below along with the capital costs of the main projects:

Table 5.2: Investment Costs in a Coal Mine Project

	Main Project	Rs. Lakhs
1	Cost of land acquisition	1598
2	Cost of civil works	5246
3	Plant and machinery	60769
4	Furniture, vehicles etc.	22954
5	F.R. preparation cost	237
6	R & D cess	315
7.	Revenue expenditure (capitalised)	1346
8	Miscellaneous	255
	Grand Total	92720
	Environment management	
1	Rehabilitation	1688
2	Compensatory afforestation	181
3	Capital for restoration	630
4	Anti-pollution measures	1190
5	Env controls in the township	331
6	Others	337
	Grand Total	4357

As against the environmental abatement and restoration costs of Rs.4356.82 lakhs, the total capital cost of the mining project is Rs 92720.21 to produce 10 5 million tonnes of coal per year. The impact of this environmental management plan is about Rs. 4.98 per tonne of coal (on the basis of annualisation of costs). The capital cost of pollution abatement and environmental restoration is about 4.7% of capital cost of the main coal mining project

5.2.3 Social Cost of Environmental Management

A large number of uncompensated (i e. external) costs are incurred by the society which are attributable to such opencast mining operations. Among them some are identifiable and many are not. Opting for coal mining now, making the choice set on the use of forest land for the future generation smaller is an example of irreversible externality. Other external effects that can be listed are (a) direct effects of loss of forests and agricultural land on ecology, biodiversity, aesthetic value of life and income (b) health effects on people reflected in their health management costs (c) extra consumption expenditures incurred to keep the houses dust and noise free, water purification and security (d) loss of livelihood due to displacement and rehabilitation All these externality costs added to the project environmental management costs yield an estimate of social costs of a mining project.

The data from the same coal mine project is used to develop some of these social and financial cost components as an illustration. The social costs are identified under two broad categories namely (a) irreversibility costs (or benefits foregone (b) direct and indirect environmental management costs. The direct project costs are treated as financial costs.

Opencast mining requiring land and forest area can be considered as an irreversible investment venture. The loss of preservation value of these is an approximate value of irreversibility cost. According to the Guidelines on forest conservation (1980) the environmental value of one hectare of fully stocked forest can be taken as Rs.126.74 lakhs to accrue over a period of 50 years. If one makes a drastic assumption of

having equal value over all the years on an equity and balanced regeneration rate basis, this preservation value works out to Rs.2.50 lakhs per hectare. Therefore, for purposes of estimating irreversibility value of forest land in coal mine areas, a norm of Rs.1 88 lakhs per hectare (assuming only 75% forestry) is applied. With a total land acquisition of 1829 hectares, but with reforestation on 110 acres of land, the total irreversibility cost or loss of preservation value works out to Rs.3231.72 lakhs An against this, there is an actual cost of reforestation and afforestation incurred by the project authority to a tune of Rs 181.28 lakhs and actual (i e direct) cost of land acquisition of Rs.1597 59 lakhs

Other direct environmental management costs are the abatement costs incurred by the project authorities. The social value or costs of such abatement measures also differ from market price based costs The components of such measures are (i) rehabilitation (ii) environmental restoration equipments costs (iii) anti-pollution measures in the township and (iv) environmental controls The social costs towards rehabilitation have been estimated by taking the entire population of the region that will be affected This includes the income loss to the families from agricultural activities, costs of rehabilitated land, costs of house building and infrastructural costs. The social cost of rehabilitation is estimated as Rs.2574.83 as against the direct financial compensation of Rs.1688.24 lakhs. Likewise the social cost of environmental restoration has been estimated at Rs.690.11 lakhs, as against the direct capital costs of Rs.630.12 lakhs

The indirect costs are such other externality costs which are not borne by the project authorities Among many possible components of these costs, only the health management costs and losses due to stress and strains of coal mining activities are analysed. They are based on field level estimates of probabilities of incidences of various diseases such as tuberculosis, chronic obstructive lung diseases, bronchial asthma, cataract, gastro enteritis etc., and the population involved. As a measure of stress and strain effects, a fraction of the expenditures on bidi, tobacco and liquor is used. These indirect social costs add up to Rs.1732.80 lakhs in the entire life time of the project.

Table 5.3 shows the components of all the relevant cost estimates in a summary manner. All costs are annualised to make them additive. Capital cost expenditures are annualised at 12% capital recovery factor. Indirect costs per year are based on simple annual average of total project life time costs.

For purposes of environmental resource planning integrated in coal project planning, land acquisition cost (in both financial and social accounting) can be treated as components of environmental management costs This is because of the irreversibility of forest and land uses in coal mining. Alternatively one can ignore the irreversibility costs and only the direct and indirect environmental management costs can be considered. Table 5.3 shows the analysis of such costs with and without irreversibility costs. With irreversible environmental losses included, the social environmental costs are about 9.13% of main coal project costs, whereas the financial costs are about 6.53%. The treatment of land acquisition as a coal

project cost and not environmental management cost makes these two ratios go down to 5.16% and 4.70% respectively.

The social cost of environmental management is invariably higher than the corresponding financial costs. In the case above, it is 40% higher when irreversible preservation losses are considered, or 12% higher otherwise The social cost on environmental accounting per tonne of coal works out to Rs.9.50 and the same on financial terms is Rs 6.81.

In a study on 'Perspective Planning and Policy for Commercial Energy' carried out by the Planning Commission, the estimated cost of environmental management in opencast mining is Rs.6.50 per tonne and Rs.1.50 per tonne in the case of underground mining operations All these estimates being on selected sample basis, it will be extremely presumptions to normatively put any standard norm for environmental management in coal mining In any event, the rate of Ps.2 50 per tonne of coal target as fixed by Coal India Ltd seems to be extremely or the low side. The estimates from the case study suggest atleast Rs.10.00 per tonne on average as the environmental management charges to be incorporated in a coal project planning.

There is another dimension of accounting of adjustments required when it comes to mining projects. This is due to the exhaustible nature of these natural resources. In so far as such resources are for human welfare over generations, their current rate of use has to be compared to their intergenerationally equitable use or preservation values The current use of any natural resource such as coal has a developmental value but at the same time it loses its preservation value. Treating the infinite time developmental

value per year as r and finite time use or developmental value as $r / (1 - e^{-rT})$, where T is the number of years over which a natural resource like coal is exhausted. Therefore, the ratio of present (i.e. finite) developmental value to the infinite time developmental value (i.e. $1/(1 - e^{-rT})$ should be treated as a loss of preservation value.

In the coal mining sector, with a discount rate of r=0.12 and an average mine life of 30 years, the premium on account of loss of preservation value is 1 028. Therefore about 2.8% of value of coal can be set aside as a cess for intergenerational compensation for loss of preservation of coal

Accounting for social environmental management costs together with this premium of exhaustibility would make a more complete accounting for the use of such natural resources in project planning.

Table 5 3 Coal Mining Investment Costs

(Rs lakhs)

	Components	Financial cost	Social cost	Ratio	Remarks
	Main Coal Project Investments				
1	All other capital costs other than land	91122.62	91122 62	1 00	
2	Land acquisition	1597 59	3438 52	2 15	The social cost is the gross preservation loss
3	Total cap cost	92720 21	94561 14	1 02	
4 (a)	Annualised total capital cost	11126 43	11347 34	1 02	
(b)	Annualised capital cost without land acquisition	10934 71	10934 71	1 00	
	Environment Management Investment				
	Direct Costs				
5	Rehabilitation	1688 24	2574 83	1 53	
6	Env management and restoration costs	630 12	690 11	1 10	
7	Anti-pollution measures	1190 47	1190 47	1 00	
8	Env controls	331 49	331 49	1 00	
9	Compensatory afforestation	181 29	206 80	1 14	This social value will be treated as a benefit due to afforestation
10	Total direct env management costs (5)+(6)+(7)+(8)+(9)	4356 82	4580 10	1 05	
11	Annualised direct env management cost	522 82	549 61	1 05	
	Indirect Costs				
12	Health loss costs	-	794 88		This is the total for the entire project period
13	Stress & strain losses		937 32		" " "
14	Total indirect costs	-	1732 20		" " "
15	Annual indirect env management cost	-	36 09		This is based on 48 years of mining
16	Annual env management cost = (11) + (15)	522 82	585 70	1 12	
17	Annual env management cost with land acquisition costs	714 53	998 32	1 40	Land acquisition is treated an an irreversible loss of preservation
18	Ratio of env management to main coal project costs (16)/(4a)	0 0470	0 0516		This is the case by treating land acquisition as main project cost
19	Ratio of env management to main coal project costs (17)/(4b)	0.0653	0 0913		This is the case of treating land acquisition as an irreversible preservation loss

6. ENVIRONMENTAL ACCOUNTING IN POWER SECTOR

Currently of the total installed power generation capacity of 64.82 GW (utilities only) in India , 18.44 are through hydel, 44.91 through thermal (either coal , gas or furnace oil) and the rest 1.47 GW is through the nuclear route. In all the cases of power generation and distribution , environmental impacts of various types and degree are involved. Often, the damages are irreversible in nature Loss of forest cover, changes in river courses, disturbed hydrological balance due to multipurpose river valley reservoirs, loss of top soil etc., are some of the natural resource related damages. Apart from these, there are pollution related hazards due to accumulation of fly ash at the power plants, emission of SO_2 NOX gases and dust particulate in the atmosphere. At a secondary level, there are still more externality problem due to transportation of coal from mine pit-head to lead-centre thermal power plant sites.

In the case of hydro projects the loss of forests, agricultural land and human habitat lead to climatic and environmental changes in addition to economic losses. All such changes can be grouped into five categories as physical, chemical, biological, economic and socio-cultural.

Among the alternative hydropower plant choices, the ones requiring dam and a reservoir leads to major interference with the natural and envrionmental systems. This is due to interference in the catchment area, submergence of area under reservoir, effects of dam on seismicity and finally interference with the down stream river course. The specific damages are on

forest biomass, wildlife, soil-moisture mix, mineral resources, agricultural and other livelihood support systems, culture and archaeological monuments, water quality, navigation, pisciculture, bank and bed erosions etc. The rehabilitation of habitat and uncertainty of dam breaks and flood bring about additional ecological, economic and psychological stresses. Government of India has enacted through legislation, specific acts to protect forests and environments that are likely to come under stress due to hydro project schemes. A document from the Ministry of Environment and Forests: Forests Conservation Act 1980 Rules and Guidelines as amended on October 25, 1992 gives both the relevant acts and guidelines to prepare project proposals involving forest lands. They also emphasise a thorough cost/benefit analysis on the environmental changes to be incorporated in the project reports. In particular, all costs of land acquisition, loss of agricultural and other incomes, rehabilitation and displacement costs and loss of bio-diversity (life cycles, hydrological cycles, biological species plants and micro-climatic etc) are to be accounted for

Coal based thermal power generation leads to both environmental damages related to coal mining and power generation involving air, water and noise pollution residual effects. They include water and air pollution in mining areas, overburden dump and hence loss of forest and agricultural land etc., solid wastes from power plants including fly ash, gaseous emissions and noise pollution, coal slurry from washeries etc.

As far as the environmental damages due to coal mining is concerned, it is dealt in chapter 5 separately. The power

plant related environmental damages can be grouped as (a) air quality (b) water quality (c) hydrology (d) noise (e) surroundings, flora and fauna (f) socio-economic hardships (g) health and safety and finally waste disposal. Ministry of Environment and Forestry has documented the standards and safety precautions to be attended by the concerned projects. The environmental impact costs and benefits of thermal projects are also to be incorporated in the main project reports.

Environmental stability measures at the power plant level include installation of pollution abatement devices to bring down the hazardous effects due to combination and water pollution, and incorporating measures to improve the ecological surroundings of the plant

Nuclear power stations involve high environmental damage factors and high risks The environmental damage ofcourse is site specific The risk factors are attributed to exposure to radiation. The international commission on Radiological Protection have set the necessity of maintaining the total doze quantum to substantially below 1000 mill per year Pollution abatement and environmental preservation costs in the power sector vary very much depending upon the feedstock route (i.e. hydro, coal or nuclear thermal) and locational factors. In the pithead based thermal power plants, environmental damages due to feedstock transportation are nil. Load centre based power plants need to incur heavy environmental preservation and management costs in solid waste disposal and pollution abatements and coal transportation.

As an illustration environmental preservation cost implications, Table 6.1 shows some estimates for hydro and thermal power projects introduced during 1980's taken from a study by Metaplanners (1989). The environmental costs of hydro projects are relatively quite high, ranging around 12-14 per cent of total project costs. In the coal thermal case, they are generally around 10%. Secondly, the environmental costs made a substantial change in the overall cost of generation through hydel route. Thirdly, there is considerable amount of variation in the environmental cost implications for variations in capacity.

Keeping such diversity in environmental cost factors in the power sector, four different alternatives in power generation technology and location are considered for further analysis

a) Hydropower project backed by single purpose reservoir for 710 MW capacity This will be the option mainly for peak load demand

b) Hydropower project backed by multipurpose reservoir for 1000 MW capacity This is a case for base load power generation

c) Coal thermal plant pithead based with 1000 MW. Base load power generation

d) Coal thermal plant load based with 1000 MW capacity.

Using the basic data, three different environmental management cost premiums are estimated. They are

(a) $\dfrac{\text{Environment investment cost}}{\text{Total capital cost of power plant without env. costs}}$

(b) $\dfrac{\text{Present value environment preservation cost}}{\text{Present value power net benefit}}$

(c) $\dfrac{\text{Difference in delivered cost of electricity with and without env. costs}}{\text{cost of electricity delivery without env. costs}}$

All the three premiums are shown in Table 6 2 In the hydro power case, these ratios range from 0.1170 to 0.3422. But, excluding the extremum of 0.3422, the range is from 0.1170 to 0.1615. In the coal thermal case, the range is from 0.0574 to 0.1616. Here again, the median range is from 0 0854 to 0.0929.

Usefulness of the premium for environmental considerations depends on the purpose As stated in section 2, for the purposes of project planning the premium based on capital cost alone or present value of capital and operating cost (i.e , either (a) or (b)) would be appropriate In that case, about 13-15 % premium on hydel project and about 9% on coal-thermal project can be considered On the other hand, if the consumers are to be charged a premium on environmental account, a premium of 12-16 % on KWH basis for hydropower, 16%
on pithead based coal thermal and 6% on load based coal thermal power distribution in chargeable

Table 6.1 Costs of Electricity Generation through Hydroelectric and Thermal Power Projects 'with and without' Environment

Nature of the Project	Installed Capacity MW	Ratio of Environmental Costs to		Cost of Electricity Generation (Rs/KWH.)	
		Project capital cost	Project capital & env cost	Without environment	With environment
Hydroelectric Projects					
A Single purpose reservoir	710	0 152	0 132	1 49	1 80
B Multi-purpose reservoir					
1 100% cost of the dam allocated to power	1000	0 132	0 117	0 57	0 67
2 100% cost of the dam allocated to power	455	0 144	0 126	0 69	0 81
3 10% cost of the dam allocated to power	24	0 105	0 095	0 84	1 01
4 50% cost of the dam allocated to power	450	0 054	0 052	1 09	1 23
C Run-of-the river					
1	1500	0 036	0 035	0 29	0 31
2	300	0 041	0 039	0 42	0 44
3	270	0 045	0 043	0.23	0 24
Thermal Power Projects					
A Pithead					
1	1000	0 085	0 078	0 [illegible]	0 [illegible]
2	420	0 163	0 140	0 72	0 8[illegible]
B Load Centre					
1	1000	0 113	0 101	1 02	1 08
2	500	0 138	0 121	1 00	1 06
3	420	N A	N A	1 34	

Notes All costs are inclusive of interest during construction

Source Metaplanners (1989)

Table 6.2 Environment Costs in Power Sector Planning

	Unit	Hydro power backed by single purpose reservoir 710 MW	Hydro power backed by multi purpose reservoir 1000 MW	Coal thermal pithead 1000 MW	Coal thermal load centre 1000 MW
1 Capital cost without env costs	Rs lakhs	16458	13258	17460	17460
2 Environmental costs	"	2501	1753	1491	1491
3 Present value costs without env costs	"	115410	117940	262648	325237
4 Present value costs with env costs	"	136991	135771	285720	349083
5 Diff in PV costs attributed env costs	"	21581	17830	23072	23846
6 Present value benefits	"	63070	133812	248332	255318
7 Premium on capital costs for env	ratio	0 1520	0 1322	0 0854	0 0854
8 Premium on PV env cost per unit PV benefit	ratio	0 3422	0 1332	0 0929	0 0933
9 Cost of power per KWH at consumer end including env costs	Rs	5 756	3 056	3 666	3 866
10 Cost of power per KWH at consumer end without env costs	Rs	4 956	2 736	3 152	3 656
11 Premium for env management at distribution end	ratio	0 1614	0 1170	0 1616	0 0574

Notes 1 Hydro power plant backed by single purpose reservoir is assumed only for peak load only
2 Hydro power plant backed by multi purpose reservoir is for base load
3 In the case of power transmission a loss of 40% is assumed
4 All the cases are developed as future projects
5 Computation of various rows
(5) = (4) - (3)
(7) = (2)/(1)
(8) = (5)/(6)
(11) = (9)/(10)

Source A study on Cost of Electricity Generation and Environmental Aspects, by METAPLANNERS, 1989, Tables 9 17, 9 18, 9 20

7. URBAN ENVIRONMENTAL MANAGEMENT:

- Case of A Sanitary Land Fill Project-

7.1 Introduction

Urban garbage and waste collection and disposal are primarily the responsibility of the 'state', due to their 'public good' characteristics. Sanitary land fill areas situated in the vicinity of towns and cities are planned methods of disposing such solid waste from urban areas. Such projects involve collection of urban garbage and waste from households, its transportation to the land fill site, and dumping. After the site is levelled, the top soil is made free from garbage and fouls, and created into a recreational green field. The underground gas produced can be put to commercial use or be processed further to generate gas based electricity. Alternatively, the site could be used for growing vegetables or for horticulture Therefore besides being an effective source of pollution control by removing municipal garbage from specific sites to garbage disposal dumps, sanitary land fills provide recreational services and are potential sources of renewable energy. To the extent that such a project controls pollution by disposing of refuse and reducing public health hazards within a city, the social cost of running it can often be lower than the private financial cost. The revenues recovered from generation of gas and electricity are additional benefits from such projects and increase their social desirability.

A demonstration sanitary land fill project, situated in Timarpur area of Delhi is used to illustrate the methodology. By evolving a measure of net benefit from such a project, this

study identifies the premium that the society may be charged towards its initiation namely,collection and disposal of garbage and hazardous waste. It could be looked upon as a premium on environmental management that disposal of garbage from cities and towns bestowed on society.

7.2 Methodology

The following benefits are considered in the calculation of 'environmental management premium' to be charged from such a project.

(1) The project has a high potential for methane gas production from waste disposed This is a source of decentralised energy supply It can be put to direct use and substitute for LPG cooking gas for domestic or commercial sector's usage Its social value is calculated by measuring the volume of LPG gas this project replaces, valued at the ruling market price.

(2) Alternatively, the gas generated can be used for power generation. Compared to other sources of power viz. hydel or thermal, the gestation period for this source of power is minimal Its benefit to the society is measured by calculating the total MWH of electricity generated from the available gas and valuing it at the shadow tariff rate for electricity.

(3) A land fill with urban garbage waste is also a rich source of manure. After extraction of gas, the decomposed refuse is saleable as manure, which has substantial earnings potential. The economic valuation of the manure (i.e. the value to the society) from such a project can be done in terms of

the opportunity cost of the quantum of chemical fertilisers it can replace.

(4) With marginal expenditure on laying of topsoil on land fill area, it can be used as a recreational park. Depending upon the soil condition and water availability, it may also be put to seasonal agriculture usage like fruit, vegetable or crop farming. Benefit to the society could be the revenue recovered from the sale of agriculture output or the revenue collected from the recreational park.

The land area under consideration is not particularly suited for vegetable farming It could alternatively be used as a recreational park The recreational value of a park in the region could be arrived at by using the travel cost approach to surrogate valuation discussed in section 2.2. The data base needed for its calculation would typically consider people's willingness to pay for the services of a park reflected in terms of entrance fees and distance travelled to reach it. However in the absence of such a data, valuation of recreation benefit to the society has not been evaluated by this method Instead, the waste disposal cost incurred by the 'stste' in assumed to be the revealed preference value of recreational benefits.

On the cost side, the project involves collection of urban garbage and waste from households, industrial areas and public places and transporting them to the land fill site. The site itself requires preparation by way of digging deep pits of about 30-40 feet on a large patch of land. The third component of costs is incurred in dumping the waste in the pits, levelling, tramping and making the top soil free from garbage

and fouls and creating a recreational green field (initially by burning and subsequently spreading chemicals and disinfectants). The generation and pumping of gas and electricity, and their distribution to the consumers would comprise the fourth component of costs. Finally planting of bio-mass grass, fruit trees, and flower plants would involve additional costs.

7.3 Computation of Benefits and Costs of the Sanitary Land Fill Project (SLFP)

Sites chosen for land fill projects are usually waste lands which when reclaimed can be put to future productive use. They may also be areas fit for agricultural use Depending upon the size of a city or town, a municipal body may set up 3 or 4 sites away from the city as sanitary land fill areas. Besides the quality of land surface, the volume of refuse available and the distance from the city are two important variables in the site selection process While the density of population affects the quantum of refuse, future developmental and expansion plans city limits affect the distance to be covered for the garbage d sal. The Timarpur project under study is an 80 acre plot with uneven land surface marked with depressions and ditches. The land area has been divided into 4 equal sized plots to be developed in phases This study focuses on one such phase which has been successfully used for gas and electricity generation by the Delhi Energy Development Agency (DEDA). The methodology for financial and economic calculations relevant for analysing this phase is equally applicable to other phases and sites.

An assessment of net benefit that a SLFP may generate involves financial and economic feasibility analysis of the project. The costs consisting of capital and operating

components are weighed against the benefit stream. While the financial analysis involves an evaluation interms of the ruling market prices, the economic evaluation involves valuation of expenses and returns interms of their 'shadow prices' or opportunity costs to the society. For example, to evaluate the benefit stream, the financial analysis considers actual revenue streams that are to be recovered from the sale of electricity, gas generation and decomposed manure The economic analysis however considers the benefit that accrues to the society interms of replacement value of the chemical manure produced at the project or the replacement value of LPG and electricity saved. Furthermore, any savings out of benefit strean is valued at its shadow price for the purpose of economic evaluation. This reflects social benefit arising out of it.

The capital and operating expenses corresponding to the four major activities at the SLEP are listed in Table 7.1. The table also lists the annual benefits that accrue from each of the four activities viz: disposal of garbage outside city limits, generation of gas and electricity and manure production from decomposed waste that may replace chemical fertilisers. The basic data that have been used for computation of cost and benefit streams are given in Annex 7.1 to 7.5. Of these Annex 7.1 - 7.3 list the technical characteristics of the project. Both financial and economic analysis of benefit cost streams are drawn up in Annex 7.6 and 7.7.

The analysis considered two alternative use patterns of land, a SLFP may be faced with·

(a) When land being used as a dump area is not fit for any alternate use, the capital cost of such land use has been taken to be zero.

(b) Alternatively, the SLFP may have an opportunity cost of land due to the possibility of being put to productive agricultural use. In that case, Rs.10,000 per year per acre has been assumed as an income loss for foregoing agricultural use, whose capitalised value is treated as a capital cost.

Table 7 1 Financial costs and benefits of SLFP

(Rs Lakhs)

S No	ITEM	CAPITAL COST		ANNUAL OPERATING COST		ANNUAL BENEFIT	
1	GARBAGE DISPOSAL AND RECONDITIONING OF LAND	Transportation cost	20 24	Labour	0 90	X	
		Land & Building	17 00	Material cost	0 045		
		Buldozer	1 00	(5% of Labour cost)			
		Putting top soil	0 50				
		Plantation	1.60				
		(@ Rs 7982 34 per acre)					
2	GAS GENERATION	Pipes	2 00	Labour	0 60	Actual Rev covered	42 03
		Boring	1 00	Diesel	5 00	Benefit to economy (o c)	109 275
		Storage	2 00	Maintenance	5 00	Net benefit	67 246
3	ELECTRICITY GENERATION	Generator	105 00	XX		Actual Rev covered	10 95
		Blower	1 00			Benefit to economy (o c)	29 565
						Net Benefit	18.165
4	MANURE	X		Loading and Transport of Manure (10% of Manure value)	6 07	Manure Value (@ Rs 300 00 per 10 MT) in the 11th year	60 70
						Equivalent fertilizer value	140.72*

Notes O C = Opportunity cost saved
X = Either does not exist or not evaluated
XX = The operating cost of electricity generation is combined with that of gas generation
* = Equivalent fertiliser value of Manure per Kg of dung based on the N P K contents, is computed using ICAR guidelines-

$P_U\,(N/46) + P_S\,(P/16) + P_M\,(K/60)$ where

N=0 30, P=0 15, K=0 30
P_U = Price of urea = Rs 3 00/Kg
P_S = Price of Superphosphate = Rs 4 00/Kg
P_K = Price of muriate of potash = Rs 2 50/Kg

Table 7 2

<u>Implications of Garbage Disposal and Environmental Preservation</u>

		Unit	Financial	Economic
1	Cost of environmental clearing and preservation $= \Sigma \{(KE+OE)/(1+r)^t\}$	Rs Lakhs	39 6956	40 1065
2	Net manure value recovered $= \Sigma \{(BM-OM)/(1+r)^t\}$	Rs Lakhs	15 7048	38 7029
3	Net cost of environmental preservation NEPC = (1)-(2)	Rs Lakhs	23 9908	1 7527
4	Gas and electricity benefit $= \Sigma \{(BGEL-KG-KEL\ OGEL)/(1+r)^t\}$	Rs Lakhs	46 6668	297 8784
5	Net preservation cost (=benefit) / Net gas & Electricity benefit = (3)/(4)	Ratio	0 5141	0 0047
6	Preservation cost (=benefit) / Net gas + electricity + manure and preservation benefits = (1) / (1)+(2)+(4)	Ratio	0 3889	0 1065
7	Preservation cost (=benefit) / Net gas+electricity+manure+preservation benefit by treating land cost as sunk cost =	Ratio	0 2822	0 0690
8	Preservation cost / Net manure, gas and electricity benefits = (1) / (2)+(4)	Ratio	0 6364	0 1192
9	Preservation cost / Net manure, gas and electricity benefits by treating land cost as sunk cost =	Ratio	0 3931	0 0741

Note For basic data and abbreviations see Annex 7 7

Given the two possible scenarios mentioned above, with respect to the cost of land, net present values (NPV) of benefits and costs were estimated. Table 7.2 gives these, both interms of their economic and financial implications. The NPV streams provide the basis for formulating two alternative measures of environmental premium

(a) In method one the present value of net cost of environment protection is treated as equivalent to the present value of its net benefit. The notion of cost in this case is indicative of the sum of money the 'state' is prepared tc spend in order to generate the resultant stream of recreational benefits. It consists of the costs of urban garbage clearance and hence environmental preservation, net of the manure value recovered from the decomposed refuse. The cost of the preservation is an expression of the collective willingness to pay by the society. It would have been incurred by society even if there were no other benefit accruing from it. However, the project generates electricity and gas also The net preservation cost, when expressed as a ratio of perceived net benefits from the sale of gas and electricity provides a measure of a premium that the society is willing to pay on and above receiving gas and electricity at subsidised rates. The premium is accountable on environmental preservation basis.

Using the information in Annex 7.6, and 7.7 the above method may be described as follows:

Environmental premium = Present value Preservation cost net of the present value manure benefit/net present value of gas and electricity benefit.

The benefits from actual generation and transmission of electricity and gas are valued at the prices actually charged by the project authorities from its consumers to arrive at the financial valuation and at their respective shadow prices for an economic valuation. The choice is guided by whether an economic or a financial valuation is being attempted. For economic valuation the net social benefit from electricity and gas usage is further revaluated interms of shadow price of investment(PK). For this purpose NSB i e. net social benefit is defined as follows·

$$NSB = Pk*s(NSBGEL) + (1-s)NSBGEL$$

Where,

$$NSBGEL = \sum_{t=1}^{11} \frac{BGEL-(KG+KEL+OGEL)}{(1+r)^t}$$

and s is the marginal rate of saving for the project benefits. For financial valuation, the notion of benefit needs no such adjustment Columns 2 & 3 for item 5 in table 7.2 indicate the environment premiums calculated using the above method.

(b) An alternate method of measuring the environmental premium Em could be defined as follows

$$Em = \frac{\text{Present value preservation cost}}{\text{Net present value of gas, electricity, manure and preservation benefits.}}$$

This approach is an extension of the first method. The notion of benefits is extended to cover all benefits emerging from the project, and not just the gas and electricity generation benefits. In order to get an idea about the relative cost of preservation, one can define Em somewhat differently as

$$Em^{*} = \frac{\text{Present value preservation cost}}{\text{Net gas, electricity and manure benefits}}$$

A further refinement of this evaluation of premium on environmental accounting is done by treating the land area used for the environmental preservation as free of cost (i.e sunk cost). Being a wasteland and earmarked for such a specific purpose, this assumption is worth examining. Items 6 and 7 in Table 7.2 show the estimates using these methods.

The above measures of environmental protection premium treat the waste disposal problem in terms of the shadow value of the project to the society, instead of looking at it purely as a tax problem The shadow value of the project is the environment premium to be charged from the society for receiving the benefits of the scheme.

7.4 <u>Policy Implications of SLFP</u>

It is well understood that SLFP is an environmentally relevant project Project planning for such an urban waste disposal proposal is integrated with creation of environmentally friendly recreation parks, play grounds for children and generating tangible gas and electricity benefits Finally, there is also the possibility of recovering compost manure.

Such an environmentally linked project can be appraised under several different policy options. To begin with, one can ask whether the waste disposal and environmental preservation is worth on its own merit. The answer is yes. As can be seen from the computations in Table 7.2, under economic evaluation, the net cost of environmental preservation is a meagre Rs.1.75 lakhs Urban waste disposal from about 2 lakh

households, developed into 20 acre recreation park is quite rewarding, with an implied cost of 0.875 paise for garbage disposal per household once and for all.

Secondly, the project also generates gas and electricity benefits. If those benefits are taken into account, the cost of environmental preservation is just about 51% of net gas and electricity benefit in financial terms and only about 0 47% in economic terms In other words, the electricity and gas generation activities can pay for the entire garbage collection and dumping in the landfill project site and yet generate financial surplus The economic cost of environmental preservation forms a very insignificant additional cost. If only gas and electricity users from this project are charged a marginally higher price of about 50% more than the present subsidised price, the entire environmental protection costs are recovered in gas and electricity charges; yet the consumer will have to pay much less than the alternative LPG price.

Thirdly, one can treat the manure benefit as independent of the environmental preservation benefits. In that case, as against the costs of garbage collection, land filling and development of the park, the combined benefits arising from gas, electricity and manure can be compared. As can be seen from Table 7.2, item 6, the financial relative cost of environmental preservation is about 38.9% and the same in economic evaluation works out to about 10.6%. Once again, one can argue that by simply charging about 39% extra (premium) on the gas, electricity and manure values, the entire cost of environmental preservation can be recovered. If we consider the case of recovering preservation cost through tangible benefits

like gas and electricity production and sale of compost manure then item 8 shows that preservation cost in financial terms is about 63.64% of those tangible benefits. Even if one were to charge these on the consumers, the market values of gas, electricity and manure will be still much lower than that from alternative sources.

Finally, one can also consider the case of land cost for the project as free of charges, in which case the premium on gas, electricity and manure works out to only about 28% (see Table 7.2, item 7).

7.5 Policy Options for Urban Planner: Payment Mechanisms for Urban Garbage Disposal

A purely financial cost based approach would indicate that a once and for all cess of Rs.11 5 per household be levied on areas of garbage collection. Alternatively, visitors to the recreation park could be charged about Rs.2/- per head to cover costs, in which case there is no need for a cess at household level. Thirdly, the users of gas, electricity and manure produced as joint products can be asked to pay a price higher than the present subsidised price, so as to recover all the preservation costs Willingness to pay such a price would still exist as the price would still be lower than that from alternative sources. The financial and economic evaluation conducted in this exercise illustrates this. The environmental premium viewed in terms of these tangible benefits is high as expressed by the ratio of costs to perceived benefits. This is so even when intangible benefits such as better environment are not evaluated.

Annex 7.1 Characteristics of the SLFP At Timarpur

Item	Units	
1.Population (within a radius of 10 kms)	(lakhs)	10 0
2 Average household size	(no)	5 06
3.Number of households	(lakhs)	1 9763
4 Area of the landfill site (phase 1)	(acres)	20
5 Depth of the pit	(mts)	10
6 Volume per acre of pit area	(cu m)	40468 6
7 Refuse per day/household	(kg)	2 0
8 Density of refuse	(kg/cu m)	250 0
9 Life of the project	(years)	11 0

Annex 7.2 Technical Parameters For Assessing Gas ,Electricity, and manure Benefits

Item	Units	
I Time required to fillup SLFP area		
(a) Total requirement of refuse to fil 20 acres of landfill area	(mill kg)	202 343
(b) Total availability of refuse per annum	(mill kg)	144 2684
(c) Time required to fill up landfill area	(months)*	17.0
II.Technical data for gas generation		
(a) Gas wells at SLFP	(number)	20
(b) Gas available per well	(cfm)	21
(c) Volume of gas generated /annum	(000 cf)	220752
(d) LPG equivalent of (c) above	(lakh) (cylinders)	1 68115
III Technical data for power generation		
(a) Power generation capacity	(kw)	365*6
(b) Power generation /annum @ 25% capacity utilisation	(lakh kwh)	10 95

Financial and economic valuation of benefits are based on these parameters
* If refuse /day/hh is marginally lower, time taken to fill up SLFP is extended to 2 years

Annex 7.3 Data Pertaining to financial and economic valuation of benefits:

	Item	Units	(Rs.)
(a)	Market price of electricity	(kwh)	1.0
(a)	Shadow price of electricity	(kwh)	2.70
(b)	Market price of gas	(per cylinder)	65.0
(b)	Price of gas charged at SLEP site	(per cylinder)	25.0
(c)	Market price of manure	(per 10 tonnes)	300.0
(c)	Opportunity value of manure i.e. equivalent fertiliser value of dung	(per kg)	69.50
(d)	Shadow wage rate of labour*	(percent)	0 67
(e)	Shadow price of diesel	(percent)	1 2
(f)	savings rate assumed out of net benefits*	(percent)	22.0

* M.N. Murty et al: National parameters for investment projects appraisal in India : April 1991

Annex 7.4

Identification of Capital Costs :

1. Land and Building

Land cost when land has alternate agricultural usage.

Net income from agriculture = Rs.10000 per year per acre
Net income from agriculture = 10000(1/1.12)ᵗ

= Rs 83044.948

Capital expenditure on 20 acre land = 83044.948 X 20

= Rs 1660899

2 Expenditure on building etc = Rs 15000

3. Total expenditure on land and building = Rs. 1675899

4 Generator cost

Cost per generator = Rs 15 Lakhs

Cost of 6 generator = Rs 40 Lakhs

One stand by generator is assumed

Total cost of generators = Rs 55 lakhs

5 Cost for pipes

Expenditure on piping per well = Rs. 10000

Expenditure on piping 20 wells = Rs.200000

6 Expenditure on boring of well

Expenditure on boring of one well = Rs 5000

Expenditure on boring of 20 wells= Rs. 100000

7 Cost of blower

Cost per blower = Rs 50000

Cost of two blowers = Rs 100000

8 Transport cost

Garbage to be carried = 20234.2 MT

Capacity per truck = 10 MT

No. of trucks required ≃ 20234.3 say 20234

Travel distance to land fill site = 10 kms

Truck kms to land fill site = 20235 X 10 = 202350 Tr Kms

Assuming empty return trips
Effective truck Kms = 202350 X 2
= 404700 Kms

Cost of truck transport = 404700 X 5 Rs

(@ Rs. 5/- Per Km) = Rs. 20.24 lakhs

9 Bulldozer cost

Charge per bulldozer hour = Rs 100/-

Total working hour per day = 8 hours

Levelling time = 120 days

Total cost of levelling = 8 X 100 X 120

= Rs 96000

= 1 lakh approx.

Annex 7.5

Identification of operating costs per year.

Item	Units	
1. Maintenance Cost	(Rs. lakhs)	5.0
2. Cost of Diesel*	(Rs lakhs)	5.0
3. Cost of Labour	(Rs. 000)	60.0
(i) Number of Labourers	(No)	3.0
(ii) Wage rate	(Rs.000)	1.5
4. Cost of Labour for reconditioning of land	(Rs.000)	90.000
(i) Number of Labourers	(No)	5.00
(ii) Wage rate	(Rs.000)	1.5
5. Material cost for (4) above (5% of labour cost)	(Rs.000)	4.5

Operating costs per year	Rs (Lakhs)
1. Maintenance	5
2. Diesel	5

* Diesel for running the generator with 20 · 80 of diesel & gas — 1 Lakh

Annex 7 6 FINANCIAL ANALYSIS OF COSTS AND BENEFITS (Rs Lakhs)

Year	K(t)			O(t)			B(t)			
(t)	KE	KG	KEL	OE	OGEL	OM	BG1	BEL1	BGEL1	BM1
1	31 79	3	0	0	0	0	0	0	0	0
2	8 55	0	0	0 945	0	0	0	0	0	0
3	0	3	105	0 945	10 6	0	42 029	10 95	42 47175	0
4	0	0	0	0 945	10 6	0	42 029	10 95	42 47175	0
5	0	0	0	0 945	10 6	0	42 029	10 95	42 47175	0
6	0	0	0	0 945	10 6	0	42 029	10 95	42 47175	0
7	0	0	0	0 945	10 6	0	42 029	10 95	42 47175	0
8	0	0	0	0 945	10 6	0	42 029	10 95	42 47175	0
9	0	0	0	0 945	10 6	0	42 029	10 95	42 47175	0
10	0	0	0	0 945	10 6	0	42 029	10 95	42 47175	0
[illegible]	0	0	0	0	0	6 07	0	0	0	60 7

For notes see Annex 7 7

Annex 7.7 ECONOMIC ANALYSIS OF COSTS AND BENEFITS (Rs Lakhs)

Year	K(t)			O(t)			B(t)			
(t)	KE	KG	KEL	OE	OGEL	OM	BG2	BEL2	BGEL2	BM2
1	33.23	5 4	0	0	0	0	0	0	0	0
2	9 225	0	0	0 648	0	0	0	0	0	0
3	0	5 4	189	0 648	11 402	0	109 275	29 565	111.5212	0
4	0	0	0	0 648	11 402	0	109 275	29 565	111.5212	0
5	0	0	0	0 648	11 402	0	109 275	29.565	111.5212	0
6	0	0	0	0 648	11 402	0	109 275	29 565	111 5212	C
7	0	0	0	0 648	11 402	0	109 275	29 565	111 5212	0
8	0	0	0	0 648	11 402	0	109 275	29 565	111 5212	0
9	0	0	0	0 648	1 402	0	109 275	29 565	111 5212	0
10	0	0	0	0 648	1 402	0	109 275	29 565	111 5212	0
11	0	0	0	0	C	6 07	0	0	0	140 7

K(t) Capital cost in t years (in Rs lakhs)
O(t) Operating cost in t years (in Rs lakhs)
B(t) Benefit in t years (in Rs lakhs)
KE Capital cost for Environment
KG Capital cost for gas
KEL Capital cost for electricity
OE Operating cost for environment
OGEL Operating cost for GAS + Electricity

OM Operating cost for manure
BG1 Actual revenue recovery for gas
BG2 value of LPG saved (opportunity value)
BEL1 Actual recovery of electricity charges
BEL2 electricity valued at shadow price
BM1 Manure value
BM2 Manure value (equivalent NPK value)
BGEL1 Combined market benefit of gas and electricity
BGEL2 Combined social benefit of gas and electricity

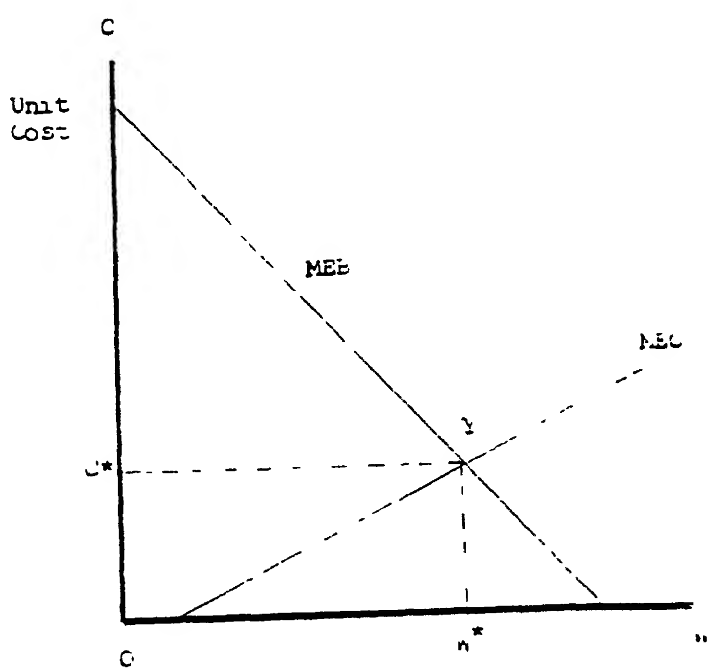
8. WATER POLLUTION ABATEMENT - A cross-industry analysis-

Industrial consumption of water can be categorised in two parts Water is used as input in several processes for dilution, transportation and as solvents. It is also used for effluent disposal and cleaning operations. It is the latter use that pollutes the environment when the waste waters carry hazardous chemicals, suspended particles and dissolved noxious gases. Such contaminated water is unfit for human consumption as well as biological and animal habitat Occurance of stomach disorders and related ailments in humans, and loss of several species of fish and consequently biodiversity are commonly heard of in the industrial areas having no check or controls on flow of such waters.

Industrial and urban water pollution can be checked broadly by two approaches with different implied technologies and costs. From the pollutor's point of view, it involves an abatement technique to bring down the effluents to some level before discharging into running water or slurry Alternatively, the receiver of the contaminated water may install mechanisms to avoid the consequences of effluents. Examples of the first are installing water treatment plants in the industrial complex. Examples of latter are use of water purifiers at home, use of potassium permanganate etc. in the wells etc.

As discussed in sections 2, 3, and 4, between the gains from installing pollution abatement devices with a view to raise his own benefit (profits) and cost to be incurred for such abatement or avoidance, one may be able to arrive at an equilibrating rate of water pollution abatement. While marginal economic costs of abatement would rise with higher levels of abatements, marginal benefits of abatements would decrease.

As long as tolerance levels of water pollution are set at this equilibrium level when MEC = MEB, the cost implications for environmental management are well identified. In the interest of the polluting industry an abatement rate of W^* incurring a cost of C^* is optimum.



Cost and Benefits of Pollution Abatement

If for any reason, any minimum standard is set much higher than W^*, then the polluting industry has no incentive to maintain such high environmental standards and may perhaps have to be subsidised as a social preference. On the other hand, if abatement standards are set lower than the equilibrium W^*, then the polluting industry may have to be taxed or penalised additionally to protect and preserve the environment in the long- run

At present Central Board for the Prevention and Control of Water Pollution with its state level counterparts is the authority to set tolerance limits, assessments, monitoring the standards and enforcements. The Board has evolved guidelines for the control of water and many other related environmental effects Minimum national standards for environmental pollution (MINAS) have been established for 10 specific industries Annexure-IV shows some selected MINAS and or tolerance limits for effluent water discharges.

In the case of water pollution, the environmental damage is identified as loss of recreational services and aquatic life These are revealed through parameters such as biological oxygen (BOD) and chemical oxygen demand (COD), suspended particulate and hazardous metals such as zinc, mercury etc. Minimum acceptable standards are set on the basis of medical, hygienic and social sample basis.

In practice, from the point of view of project planning, installation of abatement systems is important. Methodologically, the cost of abatement techniques (capital as well as operating costs) should be added to the costs of industrial projects. Here, one may be guided by the MINAS or tolerance limits prescribed by the competent authorities like the Central Pollution Control Board. In addition to this, the

social costs incurred by the receivers of polluted water, to bring the water quality to their satisfaction or tolerance may have to be imputed and charged to the polluter and subsidise the receiver. In the case study here however, no attempt is made to estimate the latter.

Costs of water pollution abatement depend upon (a) the abatement technique (b) scale of operation, and (c) tolerance standards. The implications for environmental management to tackle water pollution can be identified under polluter pay principle. The costs therefore can be estimated separately for each polluting industry under alternative techniques and scales of operation. The costs can be estimated both in financial (or commercial) terms and in terms of resource costs The resource costs are net of indirect taxes and subsidies.

The capital equipments of water pollution abatement techniques are generally turned to meet the MINAS The costs of those equipments may vary depending upon the size, magnitudes and specifications The operating costs of those equipments depend upon the type of affluents to be discharged, treatments, size of the production unit, location and product specific MINAS. Therefore, unless, one sticks to the same industrial data, it may not be possible to estimate the optimum pollution abatement as discussed earlier in this section A cross section of cost data from different industries with varying MINAS specifications and sizes can not lead to arrive at the optimum as shows in the diagram

In the absence of such cost data from the same industry following the same MINAS, cross-section of data from different industries is used to compare the unit costs of water pollution abatements across industries The capital and operating costs of water pollution abatements are taken for a

study by Murty et al (1989). They have compiled for a sample of units from different industries the water pollution abatement costs and released after treatments. A cross comparison of such abatement costs can at best provide clues to their impacts on environmental management.

Costs of abatement will have two components namely, capital or initial plant and machinery costs and operating costs In order to arrive at annual cost implications of any abatement technique, the sum of annualised capital cost and annual operating costs per unit of water used in the treatment plant or per unit of released treated water can be estimated and compared. Using the data from Murty et al (1989)

Table 8 1 Water Pollution Abatement Costs
some sample estimates·

(in Rs)

	Anualised resource cost per KL of water		Anualised financial cost per KL of water		Ratio of water released to used
	Used	Released	Used	Released	%
Agro Fertilizer	27 93	73 75	30 43	80.3[illegible]	37.88
Caustic Soda	0 87	2.65	0 89	2 72	32 7
Cotton Textile	0 26 to 4 03	0 50 to 9 20	0 17 to 2 43	0 31 to 5.55	26 93 to 79.72
Distillation	7.56	19 95	8 39	22 15	37.88
Fertilizer	6 02	21 07	6 61	23 12	28 57
Gun & Shell	0 75	0 00	0 75		.
Man made fibre	0 0[illegible] to 0 12	0 09 to 0 37	0 13	0 13 to 0 30	78 02
Metro Water	2 32	0 00	2 35		
Paper	0 78 to 1 43	1 61 to 2 96	0 86 to 1 58	1 77 to 3 27	48 3[illegible]
Petro chemicals	5 92	12 05	7 42	15 12	49 [illegible]
Petroleum Refining	0 49 to 0 99	1 02 to 2 16	0 5[illegible] to 1[illegible]	[illegible] 1[illegible] to 2 4[illegible]	47.6[illegible] to 49 25
Suga	0 2	3[illegible]	0 2[illegible]	[illegible]9	1[illegible]
Tanning	[illegible] 6[illegible] to 0 8[illegible]	1 73 to [illegible] 36	0 69 to 0 9	[illegible] 9[illegible] to 3 [illegible]	35 8[illegible] to 45 3[illegible]
Vanaspati	0[illegible]	15.8[illegible]	[illegible] 1	[illegible] 5[illegible]	[illegible] 3[illegible]

Such unit costs are estimated and shown in Table 8.1. A discount rate of 12% with 20 years as the life of the treatment plant and machinery is assumed As can be seen from the table, the unit abatement costs vary across the industries, across the firms within the same industry (depending upon scale and treatment techniques, and upon the amount of water used and released after treatment). In an industry like man-made fibre about 78% of water is released after treatment. The ratio is as low as 6% in Vanaspati The annual financial cost per KL of water used varies substantially between industrial and firms. It is as high as Rs 30.43 in agro-fertilizer and can be as low as Rs.0 13 in man-made fibre Therefore, it is obvious that it is not easy to set any standard norm of environment management cost to be imputed at the project formulation stage for different industries.

Table 8.2: Statistical estimates of water pollution abatement cost structures.

1. Log ACR = 5.7487 −0.8193 log R + 0.4253 log U
   (1.66) (−1.79) (−1.67)
   R^2 = 0.3256, d.f. = 18

2. Log CR = 5.7557 −0.7943 log R +0.3963 log U
   (1.76) (−1.84) (−1.78)
   R^2 = 0.3465, d.f. = 18

3. log CR = −0.0121 −1.0356 log (R/U)
   (−0.03) (−2.39)
   R^2 = 0.2311, d.f = 19

4. log ACR = 0.0397 −1.0581 log (R/U)
   (0.08) (−2.33)
   R^2 = 0.2217, d.f. = 19

5. log CR = 8.5574 −0.5755 log P
   (3.54) (−3.09)
   R^2 = 0.323, d.f = 20

Notes. ACR = Annual financial cost per KL of water released. (Rs.)
CR = Annual resource cost per KL pf water released (Rs.)
R = Quantity of treated water released in KL
U = Quantity of water used in KL
Figures in brackets are t- statistic values
All logarithms are to the base e.
d.f = degrees of freedom

However, one can study the cost pattern with respect to the treatec versus used water. In principle, such an abatement cost relationship should be identified for each industry and separately for different techniques. Using such marginal abatement cost relationships it may be possible to impute norms of abatement cost at the tolerance levels as explained earlier and illustrated in the diagram. But, in absence of such detailed data to estimate the marginal abatement cost structure, an attempt is made here to demonstrate and illustrate the methodology using the cross-section of various industry sample data. Table 8.2 shows the estimated regression models of abatement cost functions They are estimated for financial and resource costs explained by amount of treated water released, amount of water used and the ratio of released to used water

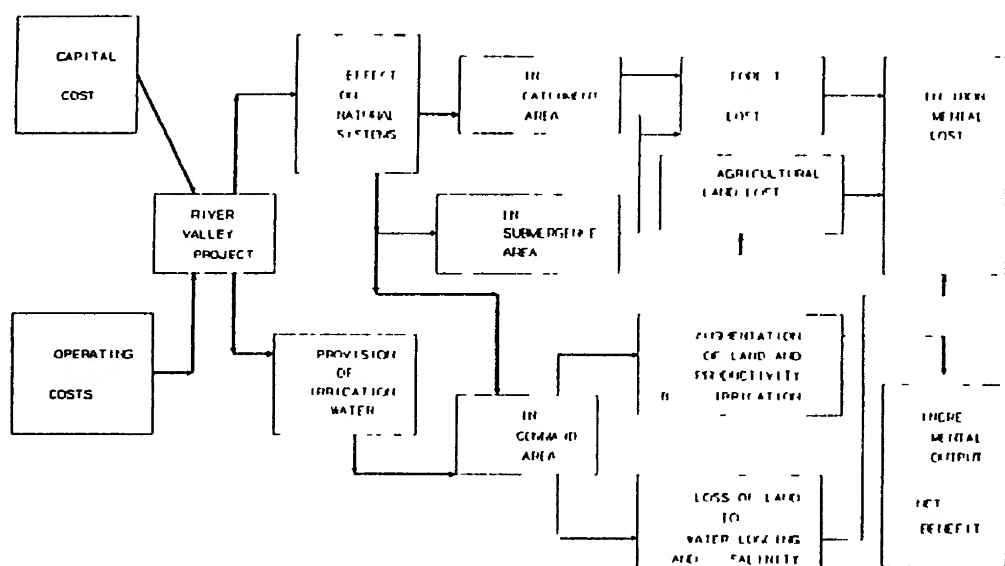
The estimated abatement cost models suggest that, generally unit abatement costs are downward sloping. One is not sure if such decreasing abatement cost structure is universally true for each industry. If so, it is clear that the well known Pigouvian tax for such externality abatement is not optimal[14]. But there are sufficient clues to suggest the possibilities of decreasing abatement costs. In such cases, the only alternative will be to set tolerance limits and standards. If one sets tolerance limits in terms of released (after treatment) to used water, one can estimate some kind of project level management costs. For instance by setting R/U=1 i.e., 100% treatment of water before releasing, the normative unit abatement costs are Rs.1.0407 in financial terms and Rs.0.9879 in terms of resource costs per kilometer of water used. Releasing 50% of water amounts to a unit cost of Rs.2.1665 in financial terms and Rs.2.5290 in terms of resource costs. From the data shown in

Table 8.1, it can be seen that in most industries, far less than 50% of water is released after treatment. Taking clue from this fact, one can only imagine the water rates for such industrial uses to be far more than an average of about Rs. three per kilo litre (to account for all resource costs).

In summary, environmental management in the case of industrial water pollution can be introduced under polluter pay principle with control standards established by an agency such as Central Pollution Control Board

DIAGRAM I

IRRIGATION COMPONENT OF RIVER VALLEY PROJECTS EFFECTS ON NATURAL SYSTEMS



9. ENVIRONMENTAL IMPACT ANALYSIS OF RIVER VALLEY DEVELOPMENT PROJECTS

9.1 Introduction

All land-using projects alter the natural systems of which they are a part Some such projects are hydel power projects river valley schemes, mining projects and projects involving extraction of forest produce (vide Annex 1). In almost all situations, such projects are not generally evaluated after duly accounting for their impact on natural systems. They are viewed individually as irrigation, power, soil conservation or mining projects. Consequently, certain changes that occur as a result of their execution impose a cost on the economy using stock of natural capital that are not accounted for Ideally, such costs should be added on to the costs of the project Such additional cost incurred per unit of incremental benefit from the project in question, i e EC/NB where EC is environmental cost and NB is net benefit from the project, is the cost of maintaining the natural system intact It can be viewed as a measure of the willingness to pay of society for maintaining the natural capital intact, expressed in terms of per unit of benefit from the project Such willingness to pay arises out of a premium that society places on the environment, i e the 'Environmental Premium'

9.2 Environmental Costs: Components and their estimation

In this chapter, it is proposed to estimate environmental costs imposed by river valley projects i.e , projects that harness river water for provision of irrigation, power and other ancillary benefits. The estimation shall consist of two stages.

1. Identifying the changes which occur due to these projects in natural systems but which have not usually included in a market evaluation. These changes would vary from project to project but parameters approximating them could be estimated from a range of projects of one kind.

2. An indirect estimation of the value to the society of these changes, by approximation to either exchange value or use value.

A number of large, small and medium river valley projects have been undertaken in India The CBIP (1989) lists such projects their environmental impact can be illustrated by taking a schematic view of the changes occurring in the natural system. As represented in Diagram 1,5 such projects involve alterations in land-use patterns in both the catchment area and the command area of the river basin These changes fall in the following categories:-

(a) Gain in effective supply of land on account of increased cropping intensity and yield on irrigated land in the command area of the canals

(b) Loss of forest land in the catchment.

(c) Submersion of agricultural land in the catchment area

(d) Loss of land due to waterlogging and salinity in the canal command and the corresponding decrease in cropping intensity and yield.

Whereas, the changes occurring under (a) and sometimes (c) are evaluated and included in the calculation of net benefit from an irrigation project, those occurring under (b) and (d) are not so evaluated and included. This happens because of the absence of markets, complete markets or well-defined property rights and lack of bargaining power of those who are affected. In the absence of a market, there are

a number of ways in which such a cost can be approximated. Some of these have been listed in Sections 2.2 and 2.3. In the context of irrigation projects, environmental costs arising out of altered natural systems in catchment and command areas (illustrated in Diagram, I) can be approximated thus:

$$EC = [CA] \times [FL] \times (VFL) + (WLA) \times (AC) \text{ ------(1)}$$

where CA : catchment area per hectare of irrigation potential created

FL · Forest hectares submerged or lost as fraction of catchment area

VFL. Water-logged area as percentage of irrigation potential created

AC : Per hectare cost of technology for abatement of waterlogging and salinity

EC : Environmental cost per hectare of irrigation potential created.

The above formula is based on the contention that while the creation of irrigation potentia has a land augmenting effect in that it intensifies land use and increases productivity, it has a corresponding land degrading effect. A part of the catchment that was afforested gets denuded and there is a permanent loss of the stream of services flowing from it. This comprises a cost to society measured by VFL. Similarly land that gets waterlogged and increased salinity in the command area can be rendered fit for use only by incurring a cost on drainage measured by AC. Benefits foregone in the first case and additional cost incurred in the second constitute two important components of the environmental cost

The other three variables in equation (1) (i.e. CA, FL and WLA) reflect the relative impact of individual projects on components of the natural system. They vary from project to project, depending on the location, rainfall in the region, the slope and nature of land in the catchment area and the characteristics of soil in the command area. These parameters shall be estimated from a cross-section of projects located in different states of the country

9.3 Forests lost benefits foregone or additional costs incurred

This section deals with the methodology adopted and estimates obtained for benefits foregone by the loss of a hectare of forest land in different states of India The use value of forest is equated to the benefit foregone. Table 9.1 lists six categories of goods and services provided by forest land, the concept of value used in evaluating these and the approximations used for putting a monetary value on such flows. All these methods are variants of those enumerated in Section 2 In general, wherever a good is marketed (e.g. timber, fuelwood, fodder or certain minor forest products) its exchange value approximated by market price can be treated as the use value. For approximating use value in the absence of markets, a number of alternatives are available. The value of loss of productivity in alternative use is one such alternative. The use-value of fuelwood, for instance, cold be approximated by the loss of marginal productivity in agriculture on account of the diversion of dung to burning in the case of non-availability of wood for fuel. The market price of alternatives for fuelwood (such as soft-coke) could be a second approximation. Opportunity cost of labour time spent in collection can also be an approximation of the user-value of fuelwood and also many other forest products.

In addition to the products, three major environmental functions or services have been identified as provided by forests. These are soil conservation, nutrient recycling through litter-fall and preservation of bio-diversity. For the first two methods similar to those identified for estimation of use value in the absence of markets are used. The value to society of the soil conservation function is approximated by the cost of alternative technology for restoration of on-site productivity or of undertaking dredging and desalting down-stream. Nutrient recycling through litter fall has been estimated as the sum of the nitrogen, phosphorus and potassium contents of the nutrients returned to the soil obtained from experimental data

9.4 Use, Option and Existence Value of Forest Produced Goods and Services

Using the methods of approximation described above and collating evidence from different sources, the present value of different streams of goods and services accruing from a forest is arrived at, which is equated to the use value to forests Forest do not yield all these goods and services in the same measure and it is this which results in the differential value of a hectare of forest land in different regions. Sixteen different forest types are found in the Indian subcontinent. These vary from tropical to alpine forests and from thorn forests to deciduous/evergreen forests[15]. More than 90% of the total area under forest in India consists of tropical and sub-tropical forests of different kinds, the remaining 10% being temperate and alpine forests. In the first instance, therefore estimates of the value of goods and services obtained from five forest types are obtained. These are tropical wet forests,

tropical dry deciduous forests, tropical moist deciduous forests, tropical thorn forests and sub-tropical forests.

Each of the above mentioned forest types produces a stream of commodities and services. They are evaluated by different methods of approximation (cf. Table 9.1). Market evaluation for instance, is used for timber. Taking account of the variation in productivity from 0.41 to 3.85 cubic meters per hectare per year[16] and the wide range in market price of different categories of timber[17], alternative estimates of market value of timber and the corresponding present value of a thirty year stream of timber production are obtained for each category of forests. These values vary from Rs. 6,315 per hectare for thorn forests to Rs. 59,257 per hectare for tropical wet forests.

Non-timber forest products too have a significant assigned value in the life of people living in and around forests. Products such as fuelwood, fodder, medicinal herbs, fruits and other biomass based food and non-food consumer goods possess use value. In addition, major environmental services are provided by forests. The value of the annual flow of nontimber products accruing from a hectare of tropical forests is given in Table 9.2 The method of approximation used in the studies from which these estimates are taken is briefly mentioned. In some cases, values obtained from two alternative methods are given. The maximum and minimum value of the annual flow of non-timber goods and services is obtained as Rs. 6,058 and Rs. 10,003 respectively. The present value of this annual flow over a period of 30 years using a social discount rate of 12% has a minimum value of Rs. 54,640 and a maximum value of Rs. 90,210. Taking account of differences between productivity of different kinds of forests with respect to non-timber goods and services,

only the minimum value for tropical and sub-tropical thorn forests which yield a smaller range of products and the maximum for tropical wet forests are considered. Table 9.3 gives the use value of five different forest types, (together with a range in some cases). This value varies from Rs.1,49,467 for tropical wet forests to Rs. 60,955 for sub-tropical thorn forests.

Two other notions of value have featured in the natural resource literature i.e., option value and existence value[18]. The option value is relevant if use of a resource implies its mining. There is considerable evidence of this in the context of clearfelling for timber[19]. Option value is therefore calculated only for the timber component of value. Resources such as forests have a special value if they are retained for future use. This arises cut of new options emerging due to technology. New uses for some kinds of species may be discovered. Consequently, the value to be attached to 'non-use' in the present is more than in the case of other kinds of capital. The notion of 'option value' reflects this weight to the future vis-a-vis the present.

Existence value is unrelated to use, present or future, by oneself or others It emerges out of the view that the natural habitat posesses a value, in terms of ecological sustainability, which is independent of any human agent and the rights of non-human species. Therefore it is best kept out of quantitative evaluation with an objective of maximising the utility of individuals in society. Of late, the focus on bio-diversity as positively related to such utility has led to a few attempts at valuing resources or natural habitats in terms of their existence value. Examples are the Grand Canyon in America and certain kinds of wild life resources in the North Arctic region[20]. The estimates obtained exhibit a wide-range of

variation; the ratio of existence value to user value varies from 0.32 to 1 1 for wild life resources to 60 for the Grand Canyon The latter is, of course, perceived as an irreplaceable resource for which existence value is the larger part of total economic value. Since existence value should be a globally determined concept, it is taken to be 90% of the total of use and option value, the percentage being taken as an average of available estimates of existence value of comparable natural resources.

The total value of different forest types defined as a sum of use value, option value and existence value varies from about Rs. 3,03,57 for tropical wet forests to Rs 1,31,647 for tropical thorn forests and Rs 1,18,233 for sub-tropical thorn forests (cf. Table 9.3). This is a measure of total value lost when a hectare of the corresponding kind of forests is submerged or destroyed.

9.5 Cost of Drainage Projects to Prevent Waterlogging and Salinity

The other kind of degradation associated with irrigation projects is waterlogging and salinity in parts of the command area. This results in decreased productivity and sometimes loss of land to cultivation. It is often said that a drainage scheme should be included in all plans for river valley projects to ensure that this kind of degradation does not occur. Other measures suggested are, lining of canals, on farm water management, and organisational change[21]. In our estimates, the abatement cost of waterlogging and salinity, is approximated by the per hectare cost of drainage schemes. This cost varies from Rs. 9,371 to Rs. 21,913 depending on technological specifications such as spacing between drains

provided. The recommended spacing depends on the soil characteristics of the region concerned. In Haryana for instance, a 25 meter spacing with a cost of Rs. 21,913 per hectare (at 1987 prices) is recommended. Another study for Orissa arrives at a cost of Rs.16,410 per hectare at 1988 prices[22].

9.6 Project Level Parameters : Forests submerged and lost and Percentage of command area rendered waterlogged and saline

These parameters are specific to the design and location of projects. Their likely magnitudes have however been estimated in this study on the basis of data from a cross-section of projects The creation of irrigation capacity for one hectare in command area of a project depends on storage capacity created which in turn depends on rainfall, slope and design factors in addition to the size of the catchment. Evidence from 105 river valley projects with irrigation components is put together to conclude that a hectare meter of storage capacity created at the reservoir level requires 7.84 hectares of catchment Making allowance for transmission losses, one hectare meter of storage irrigates about 1.1 crop hectares at the command level. This implies that 7.12 hectares of catchment are required to create irrigation capacity for one hectare of command. Alternatively, allowing for turn-over, the relevant figure would be 4.75 hectares.[23]

Further, if forests getting submerged/denuded comprise 2% of the catchment[24], 0.14 (or .095) hectares of forest area are lost for every hectare of irrigation potential created. It must be reiterated, however, that the possibility of variation in these estimates is very high. An estimate in the Narmada valley project, for instance, places the catchment/command area ratio at 1.7 and the forests comprise 41% of the catchment,

implying 0.68 hectares of forest lost for every hectare of irrigation capacity created

The second parameter that needs to be evaluated at the project level is percentage of command area likely to be rendered waterlogged and saline. State-level data on this occurrence was compiled[25] and Table 9.4 gives waterlogging as percentage of total irrigation potential created for fourteen states This percentage varies from 13.8% in Orissa to 9 25% in Rajasthan to 0.94% in Uttar Pradesh Further, no major waterlogging problems were reported in nine other states. These were mainly the eastern hilly states

9.7 Environmental Cost Estimates

Using parametric values for percentages of command area likely to be waterlogged and forests likely to be denuded/submerged per hectare of irrigation potential created, alternative estimates of environmental cost per hectare are obtained as shown in Table 9 5 Each entry in the table depicts the environmental cost of an irrigation project with catchment in a certain kind of forests and command areas in different states. States are selected on the basis of the likely correspondence of the two It is found that environmental cost is highest when tropical wet forest are degraded in the catchment and the command area is in Orissa, where waterlogging is also in a larger percentage. It amounts to Rs.31,081 per hectare of irrigation capacity created. If the catchment area has tropical deciduous forests and the command area is in Gujarat, the cost varies from Rs.15 to Rs.20 thousand. As percentage of the average capital cost of creating irrigation potential for a hectare of land estimated at Rs.35,084 (at 1988-89 prices)[26] the former cost amounts to 88.00% where the

latter is only 42 to 57%. A corresponding figure could be determined once the project location is known

Finally the environmental cost can also be interpreted as the benefit accruing from projects aiming at preservation of the environment eg., soil conservation projects or afforestation projects In other words, the premium can be interpreted as a benefit or a cost of a project depending on the impact that it has on natural systems

In general the environmental cost, while being substantial in all cases, is more sensitive to the nature of the forests degraded in the catchment then to the soil conditions in the command area This additional cost could be added to the river valley project cost to arrive at the social costs. Alternatively, the magnitude of the estimates obtained give an indication of the cost of maintaining natural capital, a national as well as global asset They provide indicators of the fiscal transfers necessary for preservation of certain kinds of forests in any proposed global governance scheme for the management of natural resources

Table 9 1

Forest products an[illegible]

Serial No	Good/Service	Concept of Value	Methods of Approximation: Short run Cost	Methods of Approximation: Long-run Cost
1	Timber and Poles	Exchange Value	Market-Price	Cost of Plantation or Regeneration
2	Fuelwood & Fodder	Use-value and/or Exchange Value	1) Market-price 2) Loss of Productivity in alternative use, e g ,marginal productivity in agriculture of manure diverted to burning in the absence of woodfuel 3) Cost of alternative Technology for fuel e g , softcoke, its market price 4) Opportunity cost of labour time in collection	Cost of fuelwood plantation - Social forestry projects Investment costs and costs of institution building for such projects
3	Minor forest Products	Exchange value and/ or use value	1) Market-price 2) Cost of labour time in collection	
4	Soil Conservation	Use value	1) Alternative technology for restoration of on site productivity 2) Down Stream dredging alternative technology off-site	Cost of soil conservation and watershed management projects
5	Nutrient Recycling through litter fall	Use-value	Experimental Data	
6	Preservation of Biodiversity	Use value in the future and in the present	1) Irreversible loss? 2) Premium on future vis a vis present	Cost infinite ? or approximated by an uncertainty premium

Table - 9.2

Valuation of Goods and Services from Tropical Deciduous Forests

Sl No	Good/Service	Method of Approximation	Value of Annual flow per hectare (in Rs) Max	Min	Source of study
1	Fuelwood	1 Price of alternate technology (softcoke)	520	285	Chopra (1987)
		2.Cost of labour time in collection	725	536	Sharma & Bhatia (1986)
2	Fodder	1 Market value of fertiliser and milk output from cattle feeding on land (for established pasture and scrubland respectively	1079 5	672	Flening in Kufshmidt et al
3	Forest prodoucts eg sal seeds, tassar cocoons, tendu leaves lacs and dyes	Cost of labour time in collection	2000	2000	Bajaj in centre for science and environment (1990)
4	Soil conservation	Value of nutrients to Restore on site productivity Dredging of downstream s l for off site costs	5652	2379	
5	Nutrient recycling	Experimental data	706	706	Mishra(1969)
6	Tourism and recreation	Secondary data	3_	16	.a in C S E (1990)
			10003	6058	

Table - 9.3

Use, Option and Existence Value of Tropical Forests (Rs per hectare)

Forest Type	PV of Timber	PV of Non-Timber		Use Value = PV of goods & services from a hec of forests (Rs.)		Option Value	Existence Value (Timber & Non Timber)		Total Value (in Rs.)	
		Min	Max	Min	Max	(Timber)	Min	Max	Min	Max
1 Tropical wet forests	59257	N R	90210	N R	149467	9481	N R	144643	N R	303571
2 Tropical dry deciduous	20778	54640	"	75418	110988	3325	71656	104025	150399	218338
3 Tropical moist deciduous	16159	"	"	70799	106367	2585	66779	99148	140163	208102
4 Tropical thorn forests	12315	"	N R	66955	N R	1970	62722	N R	131647	N R
5 Sub tropical thorn forest	6315	"	N R	60955	N R	947	56331	N R	118733	N R

Notes 1 Min and Max stand for Minimum and Maximum

2 N R stands for Not Relevant

Table 9.4 : WATER LOGGING AND SALINITY

STATE	TOTAL IRRIGATION POTENTIAL CREATED (Th. Ha.) UPTO 1990	AREA WATER LOGGED (Th. Ha.)	WLA As % of IPC
1. Andhra pradesh	3081	266.4	8.65
2. Bihar	2808	370.27	13.19
3. Gujarat	1275	90.19	7.07
4. Haryana	2069	229.84	11.11
5. Karnataka	1339	24.54	1.83
6. Kerala	483	11.6	2.40
7. Madhya Pradesh	1972	4.26	0.22
8. Maharashtra	1932	6.028	0.31
9. Orrisa	1422	196.26	13.80
10. Punjab	3869	200	5.17
11. Rajasthan	1935	179	9.25
12. Uttar Pradesh	3756	35.2	0.94
13. Tamil Nadu	1581	18	1.14
14. Jammu & Kashmir	155	1.5	0.97
TOTAL	27677	1633	5.9%

No Water logging: Assam, Arunachal Pradesh, Goa, Himachal Pradesh, Manipur, Mizoram, Nagaland, Tripura, West Bengal.

SOURCE: For waterlogging salinity CWC unpublished data from office of Member, (Water Planning)

For Irrigation Potential, Govt. of India 1989 working group on Major and Medium Projects for 8th plan.

Table - 9.5

Environmental Costs of Irrigation Project

(Rs. per hectare of catchment area)

Location of Command Area	Tropical Wet	Catchment/submerged Area Forests: Tropical Dry Decidous Max	Min	Tropical Moist Decidous Max	Min	Tropical Thorn	Sub-tropical Thorn
Andhra Pradesh	30233	22134	15680	21162	14707	13898	12624
Bihar	30953	22134	16400	21882	15427	14618	13344
Gujarat	29977	22854	15424	20906	14451	13642	12368
Karnataka	29129	21878	14476	20058	13603	12794	11520
Kerala	29225	21030	14672	20154	13699	12890	11616
Madhya Pradesh	28876	21126	14323	19805	13350	12541	11267
Maharashtra	28891	20792	14338	19820	13365	12556	11282
Orissa	31081	22982	16528	22010	15555	14746	13472
Tamil Nadu	29023	20924	[illegible]	19952	1349[illegible]	12688	11414
Rajasthan		2223[illegible]	15776	21258	14803	13994	12720

Note Min and Max stand for Minimum and Maximum

10. ENVIRONMENTAL ACCOUNTING AND PROJECT PLANNING

10.1 Summary of Findings

The methodology presented in the monograph and the case studies examined point significantly the possibilities of accounting for environmental change within a project planning framework. It is found possible to value environmental resources used by specific kinds of projects and treat environmental premium as a cost to be attributed to projects. The additional cost to be incurred by society can be expressed in different ways. It is either an additional capital cost or an increase in the operating cost. Alternatively, the price of the output could be increased by a certain percentage to account for it. In any ex ante project planning exercise such costing methods would result in a fall in the B C ratio or the internal rate of return. To recapitulate, environmental resources need to be priced and accounted for in the calculus of project planning in the same fashion as any other resource. Once this is done, such projects can be evaluated using project parameters e g social rates of discount, shadow prices of foreign exchange, labour and capital that are the same as those used in social benefit cost analysis of other investment planning projects

Chapter 2 outlines the alternative valuation methodologies for benefits and costs related to environment. Methodologies based on market prices and those based on surrogate markets are discussed. Alternative strategies of environmental control such as those using fiscal devices and standards are also examined. In this monograph, however, the focus is on an integration of environmental management with

project planning. Therefore, such alternative approaches and strategies are investigated and illustrated with different case studies.

The study on the environmental impact of coal mining, in chapter 5, lists the different aspects of environmental damages occurring from it such as top soil disturbance, hydrological changes, health effects of long lasting exposure and ground vibration and consequent seisanic changes Further, altered land use pattern in an open cast mine area, before and after mining and their consequences have to be accounted for Various accounting methods employed are-loss of earnings, opportunity costs, and replacement costs. Meeting the environmental standards through installation of abatement equipments and loss of productivity are also introduced The financial and social costs of these environmental effects are estimated at about 6.53% to 9 13% of project costs, respectively This includes the valuation of irreversible environmental losses incurred In addition, a premium of about 2.8% of the value of coal should be set aside as a cess to account for the exhaustible nature of the resources.

The case of power sector is somewhat similar to that of coal In the case of hydel power projects however, the loss of productivity and earnings (due to submergence and evacuation) become quite substantial The ratio of environmental cost to project capital cost varies from 13 to 15% for hydel projects It is about 9% for coal thermal project. If one considers both project operating and capital costs together, environmental management costs add up to as high as 13 to 34 % of total present value benefits in cases of hydel power generation. It is 9% in the case of thermal projects. Either these costs are to be built in project planning or consumers are to be charged a

premium on environmental account, of 12-16% on kwh basis for hydropower and 16% or pithead based coal thermal power supply

The estimation of environmental pollution caused by different industrial processes raises methodological issues of a different kind Here the cost depends critically on scales of operation and abatement technological options Taking the case of water pollution abatement technologies, it is shown in chapter 8 that cost differs both across industry and between industry. Annual financial costs per kl of water used vary from Rs 30 43 in agro-fertiliser Rs 0 11 in man made fibre. In this case, any meaningful estimates have to be industry specific From the present inter-industry analysis we are able to identify the range in which abatement cost would lie and the technological parameters that would determine it The abatement cost data also suggests decreasing costs, because of which Pigouvian tax principle can not be applied for arriving at optimal tax and abatement levels Instead, a method of insisting on abatement standards seems to be more logical and practical By setting standards and norms about the amount of treated water to be released , the corresponding water charges can be optimally estimated

The management of urban waste centres around the impact of production and consumption activity of human settlements A landfill project for managing urban waste is studied in chapter 7. The project also produces electricity, gas and recreation benefits. The cost of environmental management, in this case, can be borne by the households generating waste in the form of once-for-all cess or from those using gas and electricity as their supply prices (still lower than market prices!) , or from those visiting the park through a recreational fee. The relative magnitudes are specified in each

case. A methodology of revealed preference of the 'state' in preserving urban environment is employment in this analysis Opportunity cost concepts are used in valuing gas and electricity, and replacement value for the compost manure

When projects impair ecosystems, it is expected that the environmental cost shall be high River valley projects are instances Environmental costs arise out of altered natural systems in the command and catchment areas In this analysis, information from a cross section of projects is used to arrive at parameters determining these changes Forests lost in the catchment or submerged area are valued taking account of the goods or services produced by different forest types Abatement cost of waterlogging and salinity in different kinds of command areas is also taken into account It is found that the environment cost varies on average from 42 to 57% of the average capital cost of creating one hectare of irrigation potential, when 'use, option or existence' value of forests is considered If however, only use value is taken, it falls in the range of 15-20% The range of variation arises mainly due to the value of forests, arising partly out of differences in the types of forests but largely on account of consideration or otherwise of value to bio-diversity or irreversibility

This monograph adopts project planning as an instrument for environmental management This implies that environmental costs are added on to project costs either as capital or as operating costs. Alternatively, the cost of environmental management could be passed on to the consumers by increasing product prices. Table 10 1 gives the ranges within which the adjustments for environmental management would lie in the cases studied here. Wherever developmental activity impinges upon the environment in a somewhat marginal manner,

this approach is a viable one to follow. The coal and power sectors, for instance, can be managed through either increases in capital costs or in product prices. Water pollution emanating from industries could be charged for as an incremental operating cost.

The limitations of project planning approach emerge in the other two cases. Public utility services such as urban waste management are in the nature of essential services (comparable to defensive expenditures on health). The choices that are left to be made are between different fiscal mechanisms for sharing cost and setting standards between different technologies. When human intervention affects an eco-system, the magnitude of environmental cost is larger. The question of whether the entire cost be charged to the project becomes relevant. Fiscal mechanisms for sharing the cost between the project and the economy, both national and global need to be worked out. This is important, particularly when some of the irreversible damage done to the environment has national and global dimensions. From a methodological point of view, it may then make sense to examine sets of projects, which are mutually complementary in their impact on environment. It is however important to re-iterate that no process of conventional externality correction will prevent a dynamic process of increasing ecological instability from taking its course. If the environmental damage function is a discontinuous one, with costs going up to infinity beyond a certain level of production, then the only strategy available may be the reduction of production levels of goods and services. As long as there is evidence to believe that such a point has not been reached, project and fiscal instruments of environmental management are relevant.

Table 10.1

Environment Management Cost of Different Projects

	Environmental Management Cost		
	(i) as capital cost	(ii) as capital and operating cost	(iii) as addition to price of output
1. Mining projects (opencast mining)	6 5 to 9 13%	-	2.8% of coal price
2 Power projects			
2 1 Hydel	[illegible] to 15%	13% to 34%	12%-16% on kwh
2.2 Coal thermal	9	9%	16% pithead based
3 Urban based management	-	-	39% on gas & electricity or Rs 11 99 as cess or Rs 2 per visit
4 Water pollution management	-	-	Rs 1 to 2 per Kl of water released
5 River valley development projects'	(a) 15 to 20% (b) 42 to 57%	-	-

Notes · 1 Estimate (a) is based on use value of forests
(b) is based on total value of forests

10.2 Project Planning and Environmental Management

A set of policy measures for environmental management, to be undertaken within the context of project planning have been presented above It must be pointed out here that these constitute necessary conditions for creating an environmental fund/account for every project. Follow-up action will be necessary to see that the extra resources generated by adopting the above measures are in fact used in environmental preservation and not frittered away in cost over-runs, time over-runs or decreased levels of productivity

One preliminary step in this direction would be to create an environment account within every project that records the use to which the resources credited to the account are put

every year. Environmental auditing should become part of financial or performance auditing reports

Further, mechanisms and institutions may need to be created to make the best use of the resources collected under this account. For this a sectoral, areal or systems approach may need to supplement the project approach The more pervasive the impact of a particular project on the environment, the more significant shall such complementary environmental measures become. For instance, all industrial projects causing water pollution need to be viewed from a sectoral perspective and the level of total water pollution compared with exogenously determined levels (e.g those determined by the Central Pollution Control Board) Similarly, whenever afforestation is required, the institutional mechanisms for undertaking it need to be examined carefully. Alternatively, the effects of deforestation on human habitats and people's lifestyles need to be investigated in greater detail Provision of sums of money for environmental management by itself is not sufficient for environmental protection Nevertheless, it is a first step and a very important and necessary first step

In many environmental management technologies, decreasing costs are often observed. In such cases, it is to the advantage of polluters and pollutees to act on a cooperative basis to install and manage pooled or community abatement techniques. While each polluting firm should continue to contribute a fee or fund equivalent to its marginal abatement cost, the total abatement cost of the cooperative being lower, the surplus fund can be used for replacement and expansion of abatement equipments and programmes, and to promote recreational development.

One can open a debate on substitution technologies, when environmental degradations are considerably high. Till such time when substitute preservation and conservation technologies have not become viable, policy decisions on projects be based on complementarily between environmentally friendly and deadly projects and schemes. By setting projects with environmentally friendly options together with those damaging the environment, the net gain on environmental account may become positive Project clearance based on such complementarily is much more development oriented than managing through fiscal instruments Setting up of a recreation-cum-ecopark as part of a chemical plant may be an illustration The eco-park and the lake can act as substitutes for other capital intensive quality control measures

Finally, environmentally sensitive projects should be cleared only after an assessment of people's view. In this process, while people may not be averse to developmental projects, internalising their cooperation, participation and perception on environmental preservation and management can result in enduring sustainable development.

FOOTNOTES

1 Creation of land use conflict as for instance, in wetland ecosystem in many developing countries is attributed to this (see D.W. Pearce & Turner, 1990)

2 Murty and Nayak (1980) developed a model of minimising this externality cost as a Pareto optimal solution between a polluting firm and a receiving firm

3 See Dixon, J.A et al, (1986) and Hufschmiclt, M.M James, D.E , Meister, A.D., Bower, B F and J.A Dixon (1983).

4 See Krutilla et al (1972)

5 Its empirical application is based on the strong assumption that individual utility functions are comparable.

6 The successful application of this approach is strictly limited by the labour market conditions

7 It could even be arrived at through a process of collective decision making

8 Defined by MEB = MEC, optimal pollution tax = MEC at the optimal output

9 Theoretically the optimum resource allocation between 2 firms (polluting firm access to abatement technology and pollution recipient firm with access to avoidance technology) will decide the optimum pollution level and the cost there in See Murthy & Nayak (1980).

10 See Murty et al (1992) and also Markandeya and Pearce (1991).

11. Carlsson, 1988, demonstrated this using the Swedish energy systems. More recently costs of reducing Co2 emissions have been demonstrated for Korea by Hoesung Lee, for Mexico by Yolanda Mendoza (1991).
Mongia, Bhatia, Sathaye & Mongia (1991) demonstrated this for the Indian energy system.

12 This section draws much of the data from a paper by Kadeer, R.Y "environmental impacts of coal mine A cast study", diploma dissertation at IEG, 1992

13 It is not easy to assess this cost through the concepts like existence value, option value or bequest value. The region being poor, the willingness to pay estimates can become grossly biased.

14. See Pearce and Turner (1990) for a theoretical argument.

15. Diagram 1 and Tables 9.1 to 9.5 are annexed at the end of the chapter.

16. See Champion and Seth (1968) for an extensive description of forest types in India. M. Bajaj in Centre for Science and Environment (1990) gives forest cover by different forest types in India.

17. See Government of India (1988) for productivity of forests.

18 Data from unpublished sources of the forest department (M.P. revealed price of some grades of teak to be Rs.12,521 per cubic meter, for sal around Rs.1,541 per cubic meter and for miscellaneous categories around Rs 1000 per cubic meter.

19. See Pearce and Turner (1990) chapter 9 for an exposition of these concepts.

20. For details see Chopra (1993 forthcoming) here, the option value is estimated at 16% of timber value with a social rate of discount equal to rate of time preference and a life of 30 years.

21. See Brookshine et al (1983) and Brookshine (1990).

22. See Joshi (1987a) and Joshi et al (1987b) for a description of the alternative measures.

23. See Joshi et at (1987b) and Chopra (1990) Panda and Kar(1990) for the cost estimates

24 If the 18 larger projects and the 84 smaller project are treated as two separate groups, the figure becomes 6 3 for the first group and 7 7 for the second After taking account of the turnover phenomenon, whereby y hectare-meters of storage capacity taps 1 5 y hectare-meters of water, an alternative estimate is obtained.

25. Estimates are obtained with this figure varying from 1% to 5%.

26. See Table 9.4. This is based on unpublished data from Central Water Commission

27. For capital and operating costs of creating irrigation potential. See Gulati (1991)

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Environmental Effects of Coal Mining
- A Case Study

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Environmental effects of coal mining - A case study

Introduction

The coal mines were nationalised between 1971 and 1973 and the industry was re-organised in 1975 with the creation of Coal India Limited as a holding company A number of subsidiary companies were formed based on geographical distribution. In the southern region, another Government company - Singareni Collieries Company Limited operates the mines in Godavari Valley Coalfield

Coal reserves in India

Coal is the mainstay of India's energy economy and is expected to remain so in the foreseeable future. The total coal reserves (as in January'93) are estimated at about 193 billion tonnes and are concentrated in the eastern and central parts of India Out of the total coal reserves, 63 % are within 300 metres depth, 27 % occur in the depth range from 300 to 600 metres, and the remaining 10 % are beyond 600 metres The coking coal reserves constitute only 15 % of the total reserves and the balance 85 % being non-coking coals Bulk of the coal reserves in the country (73 %) are inferior grade non-coking coals occurring largely in thick, interbanded seams and located in different coal fields

Coal production

Coal production in India has increased from 35 million tonnes in 1951 to about 229 million tonnes in 1991-92 recording an average growth rate of 4 5 % per annum over the forty year period However, the average growth rate between 1971 and 1991 was 5 3 % per annum The fastest and most economical way to increase coal production was by expanding opencast coal mining Therefore, in the last two decades, large investments have been made in developing opencast mines Opencast mines which contributed only about 14 % of the total coal production in 1951, increased their share to about 28 % at the time of nationlisation (1972-73) and to 67 % in 1991-92 Compared to underground mines, opencast operations have shorter gestation periods, lower production costs and less manpower requirements This strategy helped the industry to accelerate the output of coal to meet the increasing demand at comparatively lower additional cost Figure 1 shows the trend in opencast and underground production Since nationalisation, almost all the increase in coal production has come from opencast mines Production from underground mines has stagnated at around 65 million tonnes

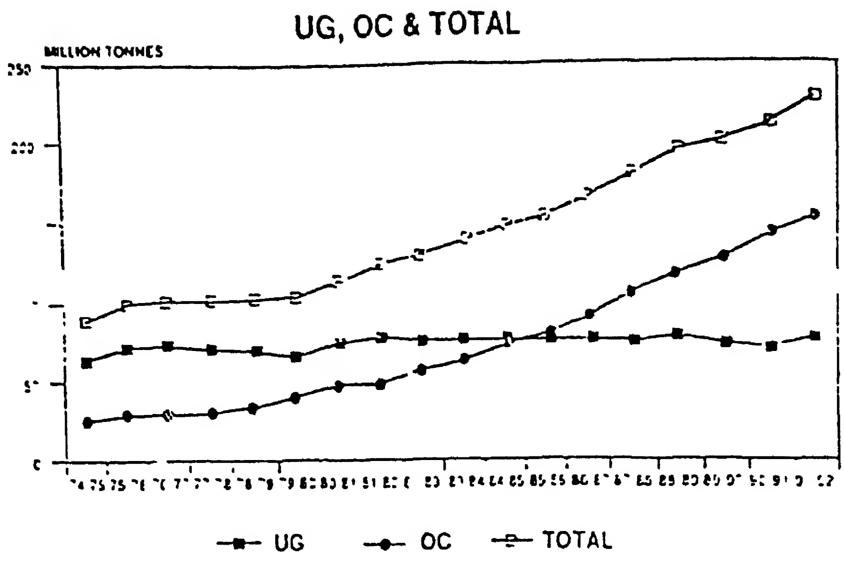

Fig 1.: Coal production

Coal consumption trend and demand projection

The pattern of coal consumption has changed significantly during the last two decades The railways, who were the largest consumer till early seventies, have adopted a policy to phase out their steam locomotives and hence, over the years, their consumption has gone down Now, the coal based thermal power stations are the largest consumers followed by steel and cement industries In 1992-93, the power sector and industrial sector together accounted for about 95 % of the total coal consumption in India The Planning Commission has projected a coal demand of 311 0 million tonnes for 1996-97, of which the power sector's share would be around 60 % The power sector would consume inferior grades of coal which would be produced largely from opencast mines

Environmental issues in coal mining

The environmental impacts of coal mining may be regarded as a chain reaction where the initial effect of coal extraction, in turn, produces other impacts which pass through the reaction chain like a series of impulses For example, the initial effect of opencast mining is the removal and deposition of waste overburden (OB) material causing land degradation at the surface Damage to land adversely affects water courses, vegetation, animal communities and man-made structures The magnitude and significance of the environmental degradation depends on the method of mining and beneficiation, scale and concentration of mining activity, geological and geomorphological setting of the area, nature of deposit, land use pattern before the commencement of the mining operations, and the natural resources existing in the area

Some of the potential impacts of mining projects on environment are as below

- ☐ Disturbance of land surface due to excavation, stacking of waste dumps, tailing ponds, workshop, haul roads, subsidence, etc
- ☐ Disturbance of ecosystem which includes flora, fauna and aquatic life

- Destruction of water sources including springs, wells, water reservoirs, etc.
- Disruption in water regime and drainage system
- Pollution of land and water courses due to erosion from waste dumps, tailing ponds, wash off from workshop and domestic effluents.
- Silting of water stream and water reservoir
- Dust pollution due to blasting, excavation, crushing, transportation, stockpiles, and tailing ponds
- Noise pollution due to blasting, movement of heavy earth moving machinery (HEMM), crushers, and coal loading operations
- Ground vibration due to blasting operation
- Destruction of aesthetic and recreation value of land

Land degradation due to coal mining

Perhaps the most serious impact of mining operations is on the land environment The extent of land degradation however varies, and is influenced by topography of the area, geology of the area, nature of soil and method of mining. Even though coal mining in India has been going on for over two hundred years, there was a spurt in coal production only after nationalisation of the mines Earlier most of the coal mines in India were underground mines and were concentrated in Raniganj and Jharia coalfields. Today, there are more than 500 abandoned mines in these coalfields There are many subsided areas which cover about 10,000 hectares of land In addition, overburden and spoil dumps created by past mining operations also occupy large areas of land Because of the damaged land, the topography of Jharia coalfields has been badly affected Mine fires have also degraded large areas of land in these coalfields In Jharia coalfield alone, there are about 70 fires covering an area of 17.32 sq km and blocking about 1860 million tonnes of good quality coal In 1989, the Ministry of Environment and Forests set up an Expert Committee to carry out macro-assessment of environmental backlog in these coalfields due to past mining operations and to assess the inputs required for restoration of such areas The extent of land degradation due to coal mining is given in Table 1

Table 1. Land degradation in mining areas (Hectares)

	Raniganj	Jharia	Others	Total
Subsided area due to past mining	5094	3497	526	9117
Abandoned area	-	1268	3632	4900
External reject dumps	370	631	100	1101
Fire area	600	1732	-	2332
Total	**6064**	**7128**	**4258**	**17450**

Opencast mining
Opencast mining pollutes the environment much more severely than underground mining. With prominent emphasis on opencast coal production in India, large tracts of land were left degraded and the attention of environmentalists thus shifted towards this major problem warranting timely control measures. There are three phases in opencast mining operation. First phase is the stripping of the overburden above the coal, the next is removal of coal itself and the third and final phase is filling up of the void with overburden material In the past not much attention was given to the environmental aspects and the first operation, i.e stripping, was carried out with considerable abandon. As a result, the soil and underlying rock strata used to get completely mixed and large areas were made sterile

The major land requirement in case of opencast mines is for mine excavation, and external OB dumps Land used for residential and infrastructural facilities form a small proportion of the total land requirements A rough estimate of land requirements is as follows.

Opencast mining

Mine excavation	- 50 %,	
Infrastructure	- 40 %	(including land for external dumping), and
Others	- 10 %	

Underground mining
The land requirement in case of underground mining is as follows,

Mine pit	- 10 %,	
Infrastructural facilities	- 20 %, and	
Others	- 70 %	(includes likely damage to land due to subsidence)

Environmental control measures

1. Land reclamation
Loss of biological productivity, deforestation, and soil erosion can be counter-balanced by adopting suitable reclamation measures and revegetation practices Land reclamation covers the problem of landscape development and the restoration of its productivity, ecological integrity and economic value The first step involves planning followed by research and development The second step is site preparation for a specific use, consisting of earth moving and grading of the surface, water regime control and sometimes the application of the productive layer like top soil or organic material on the surface The third step entails biological reclamation which will allow the development of a restored site The goal of the third step is to restore fertility and biological productivity of the disturbed land The technology and processes which are used in reclamation are dependent on the types of stripping and dumping machinery that are used and the way they are deployed In many countries, the cost of earth moving stage of reclamation makes up 70-80 % of the total costs This is a high cost-low risk activity, whereas the

cultivation and planting part of reclamation is a low cost-high risk activity Costs vary enormously making land reclamation costs difficult to estimate realistically Revegetation of the mined lands helps in controlling soil erosion and restoring the biological productivity of the area This also leads to better environmental conditions around the mine site The restored land could be used for different purposes depending on natural and socio-economic factors. The land could be used for agriculture, forestry, water bodies, or as wildlife habitats Abandoned quarries, where large voids are left, may be used for pisciculture, and water storage Land subsidence can be avoided or controlled by adopting modern techniques of mining in underground workings besides using scientific methods for predicting subsidence

Environmental Management Plans (EMP) are now mandatory for all coal mining projects The EMPs lay down in detail the procedure and technique for reclamation of degraded land for mined area and external dumps in opencast mines and subsided areas in underground mines Under favourable mining conditions, it is preferred to carry out land reclamation concurrently with the mining operation in opencast mines Absence of top soil and shortage of water in some coalfields pose challenge for biological reclamation However, in practice, land reclamation in mining areas is generally deficient and needs greater efforts

2. Air pollution and control measures

Coal mining and related activities, including transportation of overburden and coal, coal handling plants and coal washeries cause significant air pollution in the mining area Suspended particulate matter (SPM) and respirable dust are the main pollutants During mining, most of the dust arises from drilling, blasting, excavation, crushing and transportation operations Large quantities of dust become wind borne and are carried away from coal and overburden dumps

The following measures are generally adopted to deal with air pollution in mines

- Drills are equipped with dust extractors
- Surfacing of all permanent roads including haul roads is now a common feature particularly in new coal projects.
- Watering of haul roads and other roads at regular intervals Adequate fleet of water sprinklers are provided in opencast mines
- Use of chemical additives for dust suppression
- All HEMM equipment have dust proof cabins
- Dust suppression by hydro-jet spraying at receiving pit, loading point etc. In coal handling plant, a combination of dust extraction system and suppression system is provided
- Watering of active overburden dump surfaces
- Provision of green belt by vegetation for trapping dust
- In mechanised underground faces, hydro-jets and other dust extraction/suppression arrangements are provided

3. Forests as sinks for air pollutants

Intensive afforestation has to be done in the following areas so as to arrest the air-borne dust effectively. A combination of long and short trees will have to be grown and arranged in several rows in a way so as to baffle the air flow The places are:

- On both side of the haul roads within and outside the mine in 3/4 rows
- On both sides of other roads in 3/4 rows.
- 50 m wide belt along the mine periphery including the industrial site.
- 50 m wide belt around the township.
- Planting of grass/legumes along the external OB dump slopes
- Afforestation over the quarry backfilled area regularly as the mine advances

4. Water pollution and control measures

In mining industry, water pollution mainly occurs due to mine drainage, mine impoundments and fouling of water sources. Water pollution may be caused by direct discharge of mine water to the water stream and due to erosion and wash-off from the mined areas and waste dumps The water may be acidic, charged with dissolved chemicals and toxic substances or suspended solid particulates Acid mine drainage, though not common, however exists in North Eastern Coalfield, Pench-Kanhan Coalfield, Central India Coalfield and some of the mines in Singrauli Coalfield The industrial effluents are generally contaminated with grease, oils and suspended solids This effluent cannot be disposed off without suitable treatment Surface run-off in the lease-hold area also causes heavy soil erosion and if not handled properly, would cause siltation in water stream

Some of the control measures adopted in coal mines for controlling water pollution are as follows

- Water quality is determined for all important water courses traversing the coalfields as well as water impoundments
- In washeries and coal handling plants, close water circuit is adopted to prevent pollution as well as to conserve water In case of washeries, slurry ponds are also provided to allow sedimentation of suspended particles
- Acidic mine discharge water is treated with lime followed by sedimentation to make the water free from acidity and suspended solids
- Liquid industrial effluents are treated in treatment plants and oil/grease trap units After treatment, the water may be used for spraying on haul roads or recirculated for the industrial use
- Mine drainage carrying sediments can be checked and controlled prior to its joining a water body This is achieved by constructing sedimentation basins or check dams across the waterway carrying sediments to check the flow of silt or sediments to the receiving water body

5. *Ecological and social aspects*

Mining and related activities, besides altering land use, also affect the flora and fauna in the vicinity. Study on ecology involving flora and fauna have been carried out in different coalfields by zoological survey of India and state forest departments. Coal projects require relatively large areas of land for mining and infrastructural facilities This sometimes results in displacement of local population and their resettlement in a new place Rehabilitation is a sensitive issue and its success is linked with the identification of suitable land for siting of rehabilitation colonies Standard rehabilitation packages have been drawn up by the government which are being implemented in coal mining areas

6. *Impact on forest land*

In most of the coalfields, forest land is required for mining, more so in case of opencast mining Over the years, there has been degradation of forests in most of the mining areas due to mining as well as other activities Such degradation was compounded by erosion of the top soil and sub-soil In opencast mines, forest land is totally destroyed by mining excavation Forest land is normally not released for external dumps and infrastructure facilities including colonies In Underground mines, subsidence have some effect on forest land but it is control through proper mining practices Normally forest land is not acquired in underground mining areas. Guidelines issued by Ministry of Environment and Forests stipulate that the coal companies are required to undertake compensatory afforestation over an equivalent area in non-forest land or twice the area in degraded forest land (in case of non-forest land not being made available)

Case study of environmental issues in coal mines

A study was undertaken to assess the environmental impacts due to coal mining and to estimate their control costs The major thrust area of the study was the reclamation of land in the mined areas and external dumps The major objectives of the study were

- To study a sample of selected mines representing different technologies, to provide insights into various environmental issues that are associated with the application of a particular technology and provide detailed information about environmental impacts, control measures and their costs
- To develop methodologies for land reclamation in this selected sample of mines and estimate the costs likely to be incurred for reclamation
- To suggest administrative and institutional structure for implementation and monitoring of the environmental control measures

Approach

1 The Environmental Management Plans (EMPs) of the selected projects were taken as the base document The environmental control measures as given in these EMPs have been grouped under the following major heads, namely:

   - rehabilitation of the displaced population,
   - compensatory afforestation in lieu of forest land acquired,
   - reclamation of damaged land in the mine area,
   - anti-pollution measures for air and water, and
   - other provisions

2 To enable a proper evaluation of the cost of environmental control measures, the total costs (capital and revenue) have been discounted @ 12 % to arrive at the net present value (NPV) of the costs. Both financial and economic costs have been considered in the calculation The reason of considering economic cost is that these costs reflect the real cost to the economy by excluding transfer payments (duties, taxes, subsidies, and interest) from the capital costs. However, economic costs have been derived only for the land reclamation and anti pollution measures, since generally equipment costs are involved only with these items. For other items, economic costs are taken same as the financial capital costs. The cost of environmental impacts has thus been calculated using the discounted values of costs (both financial and economic) and the discounted value of coal production during the life of the project. A 12 % discount rate has been taken since it is observed that high rates are more appropriate in developing countries where the opportunity cost of capital is generally high due to shortages in supply combined with high levels of demand.

Methodology
The following methodology has been adopted.

1. Data collection through questionnaire
A detailed questionnaire for collection of data on environmental issues was prepared and circulated to 150 sample mines selected by BICP for the coal study

2. Selection of mines for the detailed study
A sample of 24 mines (from the BICP's list of 150 mines) was selected for detailed study of environmental impacts and costs. These mines were selected based on coal field, mining technology, capacity, hazards (e g. fire) etc and after discussions with concerned officials Environmental management plans were available for most of these mines and served as the basic document for the study. Some of these mines were existing mines while the remaining were either completed or on-going projects

3. Visit to the mines
TERI team visited 13 mines in different coal fields and held discussions with officials at the colliery/area/head quarters.

4. Study of the EMPs
EMPs of the selected mines were studied in detail The EMPs cover the environmental impacts, control measures and their costs Based on the questionnaire, EMP reports, and visit to the mines, data sheet for each mine has been prepared giving general information, major environmental issues, capital investment for control measures and projected cost of impacts Financial and economic cost analyses have been carried out for 16 opencast and 8 underground mines

5. Calculation of capital costs
Capital expenditure has been grouped under the following heads

- Cost of rehabilitation,
- Cost of compensatory afforestation,
- Cost of land reclamation,
- Cost of anti-pollution measures, and
- Cost of other provisions

Phasing of capital costs: The phasing of capital expenditure under each item has been worked out based on discussion with coal officials Replacement capital has been provided for the equipment assuming a life of 9 years for the equipment Costs have been spread over a period of 27 years, as it is noted that beyond this, the discounted value of the actual cost is too low to have any impact on the total environmental cost

Calculation of economic cost: For economic analysis, economic costs have been derived from financial costs for capital expenditure under items, land reclamation and anti-pollution measures A factor of 0 81 has been used uniformly for

converting financial costs to economic costs This factor has been taken after having discussions with the coal officials. The factor has been applied only for equipment used in land reclamation and anti-pollution measures

6. Calculation of revenue costs

The revenue or recurring expenditure has been grouped under the following three heads

Interest and Operation and maintenance (O & M) expenditure For financial analysis, the recurring expenditure on interest burden and O & M (both together) have been estimated as 20 % (10 % interest and 10 % O & M) of the capital costs For economic analysis, the O & M expenditure is estimated at 10 % of the capital costs (Interest is excluded). These percentages are based on the analysis of O & M costs of 13 opencast mines This recurring expenditure is assumed to be incurred from the 4th year onwards since the major items of the capital cost on equipment for land reclamation would be incurred in the fourth year Even though capital expenditure is incurred for other items from first year onwards, for convenience, the O & M expenditure is taken to start from the fourth year O & M expenditure is not charged on rehabilitation and compensatory afforestation.

Cost of biological reclamation Cost of biological reclamation of damaged land is the cost of restoration of land The different activities that are assumed to be done under biological reclamation are as follows.

- Dozing and terracing of the spoil dumps for stabilizing the slopes.
- Providing small "bund" on the outflow side from the dumps to stop the material from getting washed away.
- Plantation of grasses which bind the soil generated on the dumps, after which saplings are planted in pits especially dug for the purpose.
- Watering and other measures
- Fencing of the area.

The cost of biological reclamation is taken as Rs 50,000 per hectare of land for opencast mines and in each hectare about 2,500 trees are assumed to be planted This job is normally carried out by the state forest corporation on a contract basis This activity is assumed to start from 6th year of the mine operations. For underground mines, subsidence causes cracks and depressions on the surface land The affected land is filled with soil from nearby-areas and is levelled/graded. The plantation job is then taken up. The cost of reclamation in subsided and barren lands is taken as Rs.17,500 per hectare. As the reclamation of these lands is much easier compared to opencast mines, a lower cost per hectare has been assumed.

Cost of economic compensation. Economic compensation is to be given to land losers wherever applicable. As per the Government order, an amount of Rs.500 per month per family is to be given for 20 years as compensation to the land-losers who do not get employment in the coal mine.

7. Calculation of environmental cost
The cost of implementing the environmental control measures per tonne of coal production is calculated by applying the following equation.

$$Environmental\,cost\,per\,tonne = \frac{NPV\,of\,total\,costs\,(capital + recurring}{NPV\,of\,production}$$

The environmental cost per tonne of production capacity has been calculated for 24 mines (16 opencast & 8 underground). From these results, the weighted average environmental cost (both financial and economic) has been derived for opencast and underground mines.

8. Estimation of industry average environmental cost
The technology-wise production projection for 1996-97 in the 13 coalfields (covering the 24 sample mines) was taken from the 8th Plan document. Based on the production plan and the calculated weighted average environmental cost, the weighted average environmental cost has been calculated for the coal industry as a whole

9. Sensitivity analysis
The cost of environmental control measures for opencast mines have been subjected to sensitivity analysis The variations which have been considered are as under

- For all opencast mines, the HEMM cost for land reclamation is increased by 25 % and 50 % (to make provision for additional equipment) and its impact on the cost has been calculated for both the scenarios
- For mines with low stripping ratios, the cost of rehandling of externally dumped overburden material has been examined. The overburden material to be rehandled is taken as 10 % of the total overburden The cost of rehandling this material has been assumed as Rs.60 per cubic metre The rehandling is assumed to take place between the 18th and the 27th year of mine operation The impact of cost of rehandling on the environmental cost has been calculated

Major assumptions
Environmental management plans are now an integral part of all project reports and, for this study, these EMPs were studied carefully and the data given in EMPs have been used for the calculation purposes, however, wherever the figures were not available, they were assumed Based on the EMP data and some assumptions, the cost of environmental control measures have been calculated for 24 mines (16 opencast and 8 underground) The broad assumptions used in the calculations are as follows.

Rehabilitation package
A standard rehabilitation package for the affected population has been taken. This package is in addition to the monetary compensation paid to the land losers for acquisition of land. *The compensation for tenancy land acquired for mining*

purposes is not included in the environmental costs. The rehabilitation package includes the following.

- Plot of land (0 01 - 0 02 hectares) for each family in the rehabilitation colony
- Shifting allowance @ Rs 1,000 - Rs 2,000 per family
- Lumpsum grant @ Rs 5,000 per family
- Economic compensation to land losers, who are not provided with employment, @ Rs 6,000 per annum (or Rs 500 per month) for 20 years
- Vocational training to one-third of the population affected @ Rs.10,000 per family
- Rehabilitation colonies with certain basic facilities suchy as primary school, dispensary, roads, etc

Compensatory afforestation
It has been assumed that non forest land equal in area to the forest land acquired would be provided by the state government for compensatory afforestation The cost of such land is taken at the value of revenue land indicated in EMP Cost of afforestation is taken as Rs 17,500 per hectare or as given in the EMP whichever is higher The cost of forest growth is taken as given in the EMP or assumed based on prevailing rates in different states

Land reclamation
The land to be reclaimed in opencast mining has been assumed to be the sum total of actual mine excavation area and the area for external dumps. In underground mines where subsidence of the surface occurs, the land likely to be affected is assumed as 40 % of the underground lease hold area. However, this figure is lowered for some underground mines based on the method of mining, extent of stowing and other operations. It is presumed that the land used for infrastructure, colony, roads, etc. is not reclaimed.

Land reclamation activity can broadly be divided into the following

Technical reclamation The technical reclamation of dumps/back filled area/ subsided area is assumed to be carried out by a set of equipment as follows.

For underground mines (where subsidence is likely to occur)
The equipment are provided for loading, transporting and dumping top soil and other material in the subsided area and levelling them.

Front-end loader (1.2 m^3)	- 1
Tipping trucks	- 4
Dozer	- 1

For open-cast mines
The equipment are provided for top soil removal, dumping and rehandling and overburden levelling and grading.

Front-end loader (1.2 m^3)	- 1
Dumpers (25 tonne)	- 4
Dozers (410 HP & 320 HP)	- As per the norms derived by TERI.

The number of dozers for reclamation work has been estimated based on the following:

i. 10 % quantity of total OB material to be handled
ii. Work load of dozer for 30 m average pushing distance which ranges from 0.60 to 1.05 million cubic meters per year depending on size of dozer

Biological reclamation: The biological reclamation work would include establishing drainage, spreading soil where possible, digging pits, and planting etc. A cost of Rs 50,000 per hectare for opencast mines and Rs 17,500 per hectare for underground mines has been assumed and is taken as a recurring expenditure from 6th year onwards

Anti-pollution measures
The cost of anti pollution measures for air, water, and noise pollution control are taken directly from EMP. Wherever costs for certain items were not given, these have been assumed.

Cost analysis for opencast mines
The environmental cost analysis was done for 16 opencast mines These mines are spread over 10 coalfields and their capacities range from 1 75 to 10 5 million tonnes per annum Five dragline mines are included in the analysis The other opencast mines deploy only shovel-dumper combination of equipments The stripping ratio in these mines varies from as low as 0 5 to as high as 4 88 The weighted average environmental cost per tonne for opencast mines works out Rs 12 57 (Financial) and Rs 9 35 (Economic) The break up of the total environmental cost under the major items has also been calculated for each these mines. It is observed that cost of land reclamation and anti-pollution measures together account for 64-88 % of the total environmental cost Cost of rehabilitation and compensatory afforestation are site specific and there is a large variation in these costs The cost of land reclamation ranges from 15-36 % of the total cost

A number of graphs and charts have been plotted to establish relationships between the environmental cost, mine capacity, stripping ratio, etc

A study of these graphs/charts reveal the following

- The environmental cost per tonne of capacity increases with increase in stripping ratio but decreases with increase in mine capacity
- The land reclamation cost also increase with increase in stripping ratio and decrease with increase in mine capacity These costs relate only to the minimum reclamation tasks that are being planned Any additional task like levelling and grading, reducing heights of dumps, or contouring to as near as possible to original contours, will entail additional costs. If dumps created by draglines are to be made workable for reclamation, this may need an additional dragline, in addition to the complement of dozers already provided
- The cost of anti-pollution measures decreases with increase in mine capacity

Cost analysis of underground mines

In the eight mines that have been analyzed, different technologies of coal mining like mechanised longwall, bord and pillar etc have been adopted One mine has adopted fully stowing operations, while 4 mines have fully caving operations. Other mines have both stowing and caving systems These mines are spread over 8 coal fields and their capacities range from 0 15 to 1 5 million tonnes per annum. The weighted average environmental cost per tonne works out to Rs 11 37 (Financial) and Rs 8 99 (Economic).

The break-up of the total environmental cost under the different items have also been calculated for each of these mines. The costs of rehabilitation and compensatory afforestation are site specific *The major cost item in underground mines is anti-pollution measures which ranges from 44 to 82 % (excluding the mine, where it is only 17 %).*

An analysis similar to that of opencast was also done for underground mines and graphs have been plotted to find out the relationship between environmental cost, mine capacity and cost of anti-pollution measures The following points emerge from these graphs/charts

- The environmental costs decrease with increase in mine capacity
- The most important item in the total environmental cost is the cost of anti-pollution measures which varies from 17 to 82 % This cost also decreases with increase in mine capacity.
- The land reclamation cost is only a small fraction of the total costs.
- In seven out of eight projects, no rehabilitation is involved, as these are existing mines under reorganisation.
- Compensatory afforestation is site specific

Estimation of industry average environmental cost

The objective of the whole exercise was to derive an average environmental cost for the coal industry as a whole This has been calculated based on weighted average cost of impact for opencast and underground mines and the production plan in 13 coalfields The details are given in Table 2.

Table 2. Weighted average environmental cost for all mines in 13 coalfields

Mining technology	Production (MT)	Environmental cost (Rs/T)	
		Fin.	Eco.
OC UG Total	169 46 52 56 222.02	12 57 11 37	9 35 8.99
Estimated overall environmental cost per ton (Rs)		**12.29**	**9.26**

These environmental costs reflect only the minimum control measures that are required. Land reclamation forms a major component of the cost but here only some amount of levelling and grading and tree plantation has been considered as land reclamation. Any additional work will involve more HEMM equipments and will substantially increase the environmental cost. For underground mines, the cost of reclaiming subsided areas In working mines is not significant because it is reported in all EMPs that subsidence will be within limit and spread over many years

Sensitivity analysis

a) A 25 % increase in HEMM cost increases the environmental cost by 2 9 to 8.6 %.

b) A 10 % rehandling of overburden material for filling up the void increases the environmental cost by more than two times This analysis has been done only for mines with low stripping ratios where ultimately void would be left in the excavated area *Analysis clearly shows that the cost of rehandling is prohibitive.*

Institutional structure for implementation and monitoring of environmental control measures

Environmental management involves three major functions namely environmental impact analysis, pollution control, and monitoring It requires a multi-disciplinary team to deal with these functions The activities under each function are given in Figure 2

Environmental impact analysis: Environment impact assessment consists in establishing values for selected parameters which indicate the quality of the environment before during and after the proposed development activity Major activity in the environmental assessment process is impact prediction and assessment This involves projecting the environment setting into the future without the proposed action and then performing the necessary calculations or studying the approaches for actually predicting the impact of the proposed action and assessing the consequences. One of the first step in the environment assessment process is to describe the environmental setting for the area This provides baseline data against which prediction and assessment of the impacts of the proposed actions and alternatives can be compared

Environment pollution control: If the environmental quality standards (for air, water, etc) are exceeded by the proposed action, then abatement strategies on control measures should be presented Various control technologies can be used for minimising pollutant emissions Implementation of various control actions is also the function of this group

Guidelines for environmental monitoring: Management must provide adequate for a project environmental monitoring system Such a monitoring system needs defined objectives, a technical programme and a management structure geared to environmental concerns Otherwise, environmental monitoring may take place in an atmosphere of conflict and confusions Periodic environmental monitoring reports (quarterly) should be prepared which documents environmental impacts and remedial actions taken

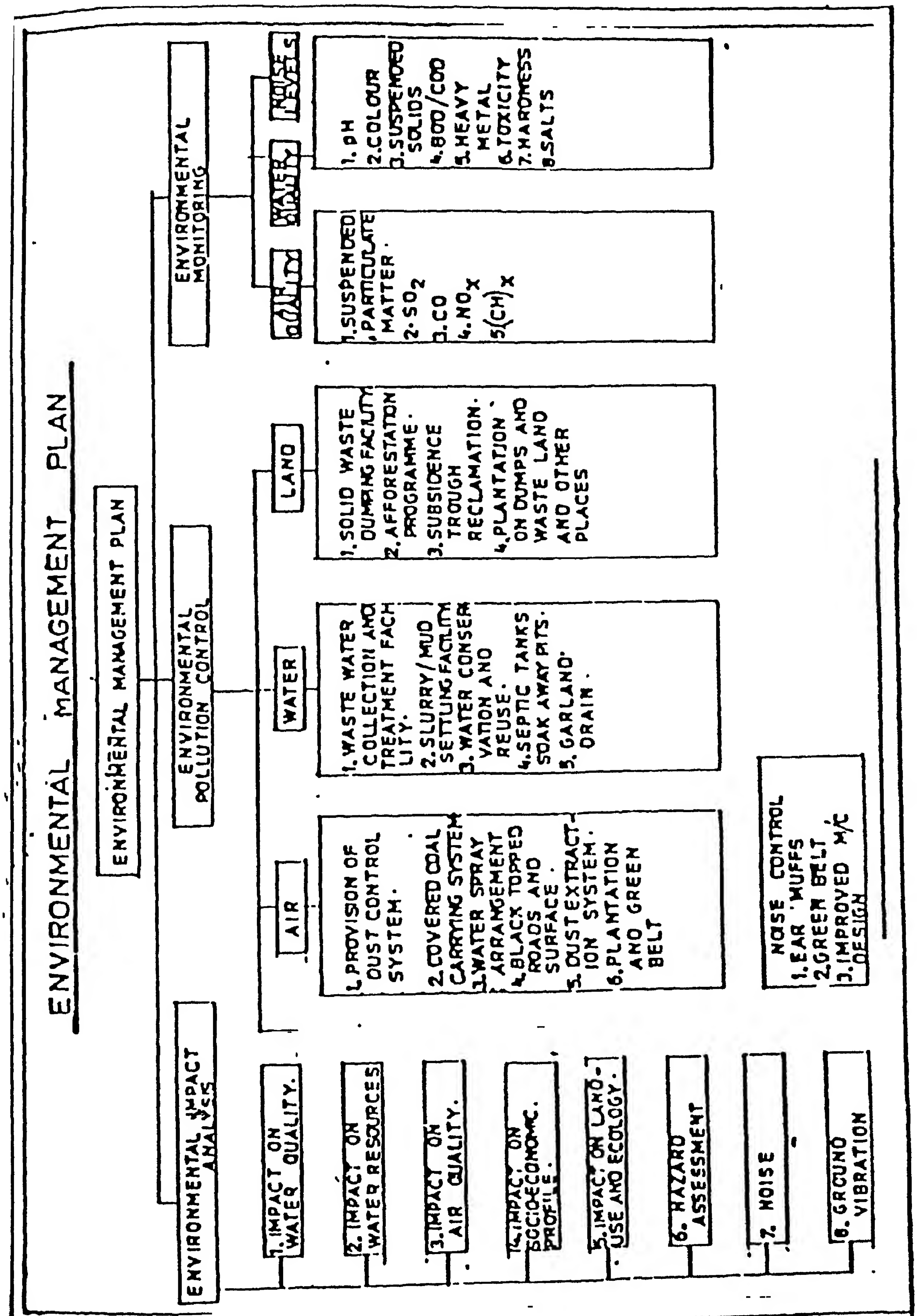

Fig 2.: Environmental Management Plan.

Recommendations

- It has been observed that costs pertaining to environmental control measures are not separately booked and are generally shown under the mining costs. Therefore, it becomes difficult to compare the budgeted costs (as per EMP) with actual cost It is therefore necessary to introduce the system of booking environmental costs separately.

- No uniform guideline is adopted for provision of equipments in the EMPs. In the study, the number of dozers for land reclamation has been worked out based on manufacturers norms for work load and amount of material to be handled in levelling/regrading work. These norms could be adopted for provision of dozer in opencast mines for land reclamation

- The regrading of external dump and backfilled areas to safer gradients (25^o-28^o) is essential for dump stability and also to facilitate restoration work The methodology for carrying out this task is explained briefly in many EMPs. But this operation is not being done in many mines mainly due to operational problems This methodology therefore should be applied for regrading dumps and backfilled areas by carrying out the actual reclamation task in one or two coalfields Based on this experiment, cost and other parameters can also be developed However it was observed during our visits to various mines that some plantation work is being attempted on the existing dumps without any regrading.

- Only the minimum quantity of overburden material should be dumped externally and as far as possible backfilling operation should go concurrently with mining operations. The study reveals that the cost of rehandling of external dumps is prohibitive

- The cost of various items under anti-pollution measures given in EMPs of different mines vary widely. The factors which affect these costs are mine capacity, CHP capacity, mine area, garland drain, sedimentation tanks, water treatment plants, metalling of haul roads and other roads, colony size, and location, etc All these costs can be standardised depending on the above factors

- The biological reclamation cost has been assumed as Rs 50,000 per hectare for opencast mines and Rs 17,500 per hectare for underground mines Some forest corporations are charging much higher rates for plantation in subsided areas It is suggested that this cost also is worked out in detail after experimentation in selected coalfields The experiment has to be carried out in external dumps, backfilled areas and subsided areas separately for a period of 3-5 years. Guidance and assistance should be taken from State Pollution Control Boards, State Forest Departments, Agriculture Department and various other agencies involved in these type of activities

Environmental Impact Assessment of large scale methods of power generation - An overview of methodology & capacity building in this area

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1. Introduction

It is generally assumed that a rise in the standard of living is associated with increasing energy use. The availability, and consequently the growth in electricity usage brings about an upliftment in the socio-economic environment thereby leading to higher living standards. On the other hand, large scale generation of electricity is invariably accompanied by adverse environmental impacts in the form of health, social, and ecosystem degradation, the magnitude of which depends upon the location as well as the type of generation. It is therefore imperative to examine **holistically** in a common framework, the positive and negative impacts from power generation The procedure for doing this is called environmental impact assessment, better known as EIA

Before we launch specifically into capacity building in this area, a brief overview of the concepts of EIA are presented in the following section This is followed by EIA as applied to large scale electric power plants.

The paper concludes with a discussion of infrastructural aspects (data needs, technical skills, etc.) which need to be provided before embarking on a mandatory EIA policy

2. Overview of the EIA process

2.1 Conceptual Definations

The concept of environment is broad based and includes physical, biological, cultural and socio-economic dimensions. These complex set of factors such as air and water quality, conservation of plant and animal life, etc affect man's quality of life and eventually his very survival

The concept of environmental impact can best be understood as any alteration of environmental conditions or creation of a new set of actions under consideration. The focus is on essentially those factors that are most affected.

Environmental Impact Assessment (EIA) is an activity designed to identify and predict the impact on the biogeophysical environment and on man's health and well being of legislative proposals, policies, programs, projects and operational procedures and to interpret and communicate information about the impacts (Munn, 1979).

2.2 Overview

The EIA can be broadly divided into the following steps, viz. basics, environmental setting, and impact prediction and assessment

2 2.1 Basics: First and foremost one must have a fair understanding and knowledge of the study Starting with the need for the project one must identify alternative solutions to meet this need. Also with these solutions a no-project alternative should be included Since impacts due to alternative solutions may widely differ depending upon the alternative itself it is necessary to broadly examine each alternative and the factors that are most affected With this information one can then select an interdisciplinary team for a particular project. It is generally recommended that the team should at a minimum consist of a physical scientist or engineer, a biologist and an archaeologist supplemented by inputs from economists, sociologists, geographers, etc (Canter, 1977) It is also important to know the guidelines of agencies such as pollution boards, Ministry of Environment, etc , so that one can carry out the work accordingly.

2 2 2 Environmental Setting· This is the description of the existing environmental factors for the project study. It provides baseline information against which predictions and assessments of the impacts for each alternative can be compared Broadly speaking, the factors can be classified under physical-chemical (e.g air and water quality, soil fertility, etc) biological (flora and fauna), cultural (archaeological sites, recreation, etc) and socio-economic (population characteristics, economic state, etc). The important feature in describing the environmental setting is to ensure that all factors that need to be considered are included, while excluding all other factors that require extensive effort to procure and have little environmental impact

2.2 3 Impact Prediction and Assessment. This is a complex task involving widely different techniques in differing disciplines The aim here is to predict the impact and then present it in a form that facilitates decision-making As measurement techniques vary, interpretation varies, and therefore a number of methodologies have been developed for presentation of these impacts to decision makers and the general public

2.3 Methodologies for Environmental Impact Assessment

The type of methodologies can be generally categorized as follows·

1 Adhoc
2 Checklists
3 Matrices
4 Networks
5. Overlay techniques

Each of these techniques display a wide variety in conceptual framework, data format and requirements, and technical sophistication.

2 3.1 Adhoc: These were the first methods to be used in the preparation of EIA. The procedure involves the bringing together of various experts in particular fields to identify impacts in their area of expertise The environment is generally divided into broad categories, the assessment of which could be intuitive or subjected to qualitative interpretation of quantitative results The adhoc approach has little or no formal analytical structure and at most provides only a preliminary review.

2 3 2 Checklists: This method is basically a variant of the adhoc method in the sense that it starts with a list of potential impact areas for which individual impacts are assessed Checklists can be of various types ranging from simple to fairly sophisticated Simple checklists have no guidelines on how to measure and interpret environmental impacts. Descriptive checklists are more structured with identification of environmental parameter and guidelines on how parameter data is to be measured. Scaling checklists go a step further by providing information on

how the parameter values are scaled. Lastly, there are scaling-weighting checklists that provide additional information on relative weights of importance of each parameter.

An example of the scaling-weighting checklist is the Environmental Evaluation System developed by Battelle Columbus Laboratories as described in Canter (1977). This was developed for application to water resources projects. It consists of a description of the environmental factors included in the checklists as well as instructions for scaling the values of each parameter and assigning importance units. Two alternatives are considered, 'with the project' and 'without the project' The approach here is to evaluate the expected future condition of environmental quality 'without the project' and 'with the project'. The difference in environmental impact units (EIU) between these two conditions constitutes either an adverse (loss in EIU) or a beneficial (gain in EIU) impact. Mathematically this process may be represented as.

$$E1 = \sum_{i=1}^{m} (V_i)_1 W_i - \sum_{i=1}^{m} (V_i)_2 W_i$$

where	E_1	=	environmental impact
	$(V_i)_1$	=	value of environmental quality of parameter i with the project
	$(V_i)_2$	=	value of environmental quality of parameter i without the project
	W_i	=	relative weight (importance of parameter i
	m	=	total number of parameters

2.3 3 Interaction Matrices This method develops on the checklist method by incorporating a list of project activities to a checklist of potential impact environmental characteristics Developed by Leopold et al. (described in Canter, 1977) the method involves the use of a matrix with 100 specified actions and 88 environmental items. Each cell represents an impact that is a result of interaction between an action and an environmental item. As with the EES two aspects of each impact needs to be determined, namely, magnitude and importance Both of these are assigned a numerical scale from one to ten.

Mathematically speaking, let

M_{ij} = (±) magnitude of the j^{th} action on the i^{th} environmental factor

W_{ij} = importance weighting of the j^{th} action on the i^{th} environmental factor

We have,

Total impact on the i^{th} environmental factor from all actions $= \sum_j M_{ij}W_{ij}$

Total impact on the j^{th} action on all environmental factors $= \sum_i M_{ij}W_{ij}$

Total project impact $= \sum\sum_{ij} M_{ij}W_{ij}$

It is possible to expand or contract the matrix, i e. action or environmental items not included can always be added and vice-versa i.e items or action having no relevance to the project under question can be deleted.

It is also possible to represent cell entries as qualitative estimates of the cause effect relationships. An example of this is shown in Table 5 (Rau and Wooten, 1980)

2 3 4 Networks: Network approaches can expand on the matrix theme by introducing a cause-condition-effect network which allows identification of cumulative or indirect effects. The network is depicted in the form of a tree, called a relevance or impact tree, and is used to relate and record secondary, tertiary and higher order effects. Since there is an uncertainty included whether or not the identified primary, secondary and tertiary impact will actually occur one needs to weight these branch impact scores by their probability of occurence. Adding these weighted scores across all branches leads to an "expected environmental impact score" given by,

Expected Environmental Impact Score $= \sum_{i=1}^{10} P_i$ (impact score of branch i)

2.3.5 Overlay techniques: This methodology essentially consists of developing a set of maps of environmental characteristics such as physical, social, etc. for a project area and overlaying these maps (transparencies) to create a composite map which shows the spatial distribution of the selected impacts The overlay approach is generally effective in its ability to set a proposed project within a geographical context and to indicate spatial relationships between the environmental factors that are regarded as relevant to the assessment of the project. However it cannot be used to identify impacts or identify secondary and tertiary relationships The method has been used to identify the optimal routing for transmission lines and site selection processes for coal and oil related developments (Codoni et al , 1985). The method was also applied on the Huasai-Thale-Noi Road Project in Thailand where the project was halted due to environmental concern. An alternative route was determined by using rough overlays of the environmental site selection parameters (Lohani and Hamil, 1986).

3. EIA of large scale electric power plants

India produces electricity mainly from coal, hydro, and from nuclear albeit in a limited way Figure 1 shows environmental impacts from the three power plants (Luthra 1992) The environmental impacts from each of these modes are widely different Also within each type, differences in magnitude arise due to locational features, type of inputs, equipments, etc. Therefore there is no generic assessment that is possible and every prospective power plant needs to be individually evaluated on a location-specific basis

Broadly speaking, the setting up of a power plant leads to growth and development in that area These benefits would arise irrespective of the type of power plant The negative impacts occur through the air, water, and land media, and is type and location-specific The issues/methodology for quantification of the impacts and their relative weighting for different type of power plants are briefly discussed below

3.1 Coal based thermal power generation

3 1 1 Air Pollution. Air pollution occurs as a result of the emission of oxides of sulphur (SOx), oxides of nitrogen (NOx), particulates (SPM), carbon dioxide (CO2), hydrocarbons (HC), radionucleids and aldehydes SPM, SOx and NOx, for which ambient standards exist, have an effect on both human health as well as the ecosystem, the extent of which is determined by the dosage received, the time span over which it is received and the average well being of the recepient population

SPM Control· Pre and post combustion control measures exist for all the major pollutants At present, the installation of electrostatic precipitators (ESP) for the control of SPM emissions are mandatory in India The average cost of SPM control by ESPs is approximately 1 % of the cost of generation. ESP usually operate at efficiencies of 99% and above. Fabric filters are preferred for their high overall collection efficiency, which is maintained over a wide range of particle sizes For submicron particles, bag filter systems in terms of collection efficiencies are superior to all other control technologies. Overall costs are also higher than ESP.

SOx Control Given the low levels of sulphur in most Indian coals, the emissións of SOx in most cases are likely to fall within ambient standards (stack emmission standards are defined only in terms of stack height). Only those areas that are already having high sulphur emissions such as the Singrauli area or in certain metropolitan cities would require Flue Gas Desulphurisation (FGD) equipment. Damage from SOx emissions are maximum in areas which already have heavy particulate loading FGDs typically operate at efficiencies around 90% and contribute to a 25-30 % increase in the cost of generation.

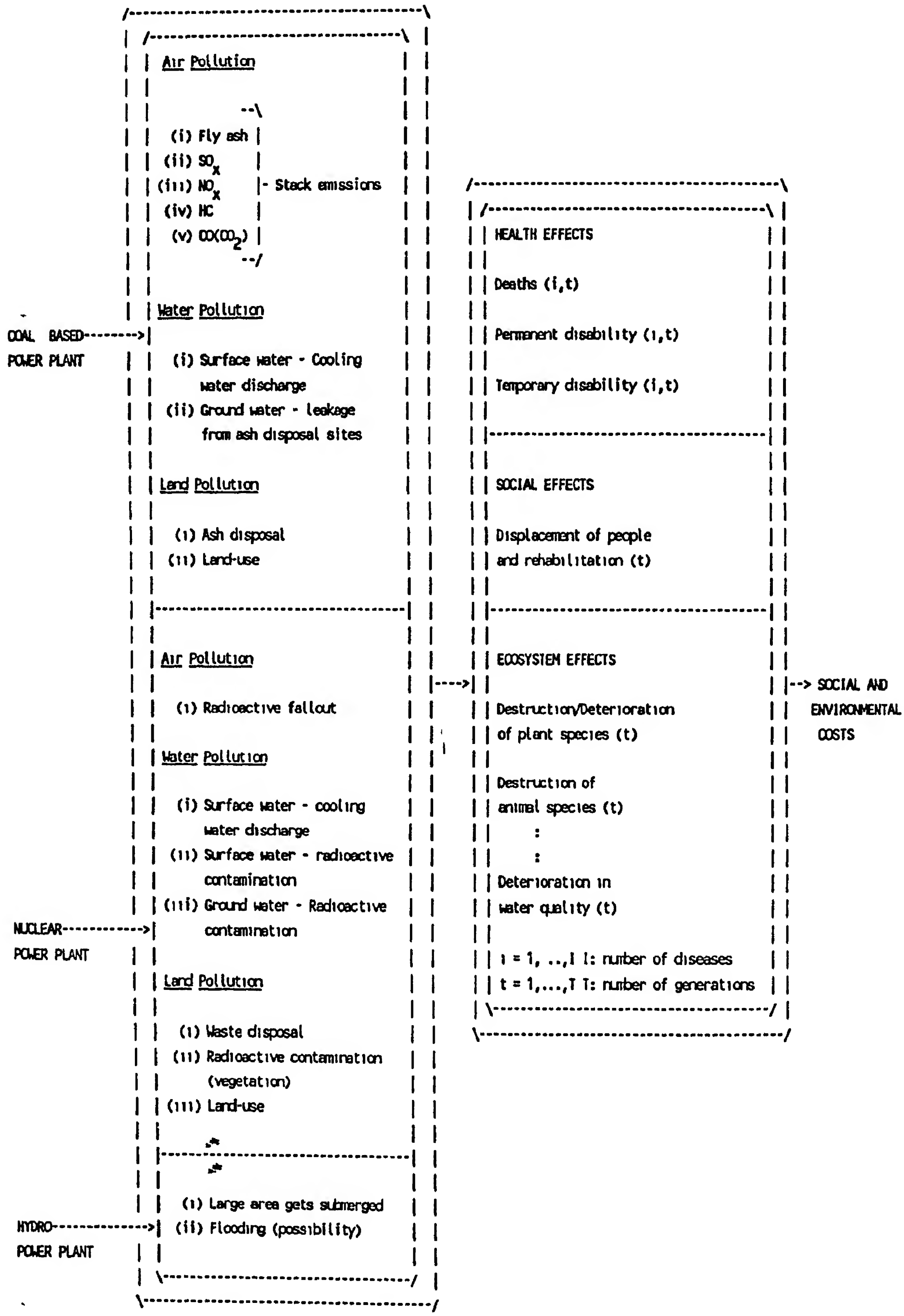

Fig. 1. Impacts of electric supply from coal, nuclear and hydro-electric power plants.

NOx Control Till recently, NOx emissions were never considered significant contributors to environmental degradation. However, in recent years increasing attention is being paid to the environmental damage from NOx emissions and methods to reduce it. Low NOx burners provides an inexpensive way with operating efficiencies below fifty percent Selective Catalytic Reduction (SCR) equipment operate at efficencies of approximately 85% but increase the costs of generation by approximately 7-10%.

Quantification of environmental damage: The damage caused due to air pollution from a power plant would depend upon the dosage received by the surrounding population, as well as their physiological, socio-economic and health characteristics.The dosage received by the population is a function of both the ground level concentrations as well as the period over which the population is exposed. Short term high concentration doses can be as potent, or in some cases more dangerous, than long term low concentration doses

Concentrations are generally computed on a short term (less than 24 hours), seasonal and on an annual basis Their levels depend upon both the technical features of the plant (quantity and characteristics of the fuel used, type of plant and state of operation, height of stacks, etc) and atmospheric conditions (wind directions, atmospheric stability, etc.) These can be computed using several approaches, the most commonly used one being the Gaussian Dispersion Model. TERI has developed a Gaussian Dispersion model. This model predicts the short term and long term pollutant concentrations with reference to the emission source, given the inputs of wind speed, wind direction, source emission rate and atmospheric stability. Figures 2 and 3 show NOx emissions under short term and long term conditions for a power plant located at Bombay. In order to determine the exposure, the seasonal/annual concentrations from the plant will be added to the background concentrations, the sum of which when mapped to the surrounding population would give the total exposure However, the mapping of pollutants onto the recipient population, requires dose-response curves of the population (these could vary largely depending upon the make-up of the population). Therefore the estimate of damage is based on air quality standards. A value function curve for air

pollution will range from say 0 to 10 (ambient standards and above corresponding to 0 and clean air to 10).

3.1.2 Ash Disposal: Given the high percentage of ash in Indian coals (averaging 40%), significant quantites of both fly and bottom ash are generated (80:20 respectively). The ash can be disposed or utilised in a number of ways

Disposal. The most common disposal method is the wet disposal system. In this system, the ash is transported by slurry pipelines and deposited at the disposal site in a fluid state. Every tonne of fly ash requires approximately 8-10 litres of water to convert it to slurry. System differences arise in terms of how the transport water and supernatent are handled in terms of treatment and discharge, recycle, evaporation or impoundment. Land requirements are roughly 0 4 ha per MW installed capacity The primary advantage of wet systems are that they are simple, relatively inexpensive to operate and normally unobstrusive (quiet, no fugitive dust, no transport traffic). They are also flexible with respect to short term variability. The main disadvantages are associated with the disposal site A large disposal area is required due to the large volume of effluents. Preparation of the disposal site requires dams and dykes which increase the cost Control of leachates (discussed below) and prevention of ground water contamination is more difficult to ensure, and liners are required Flexibility to long term changes are less

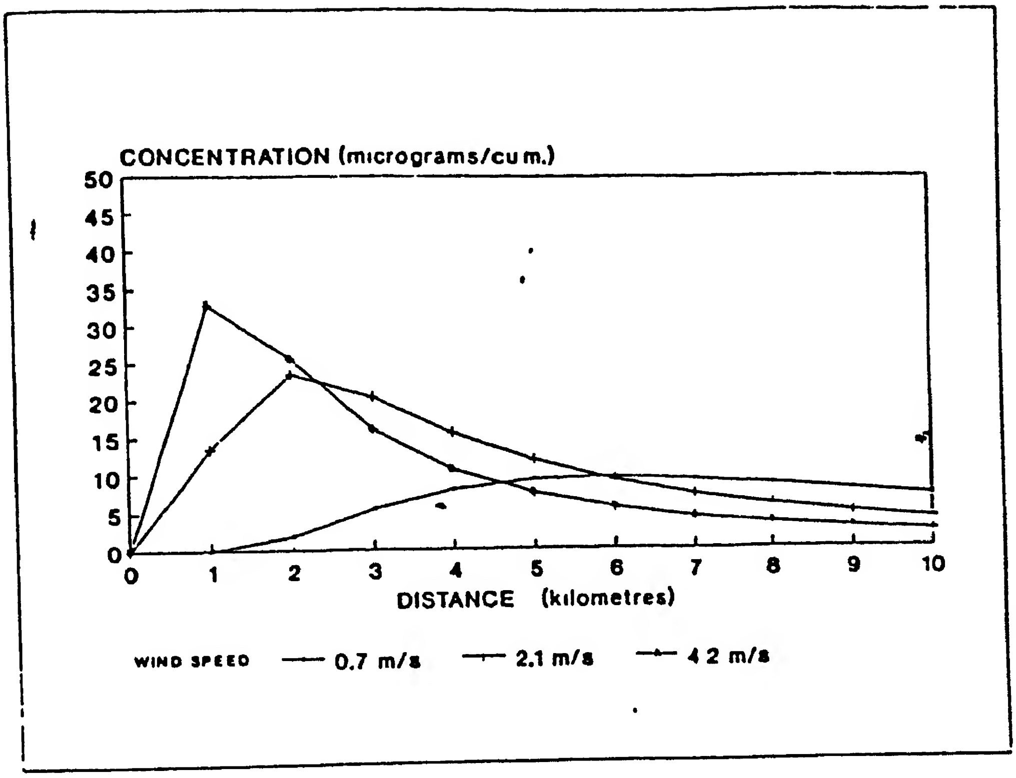

Fig. 2. Short-term concentrations of NO_x from a power plant.

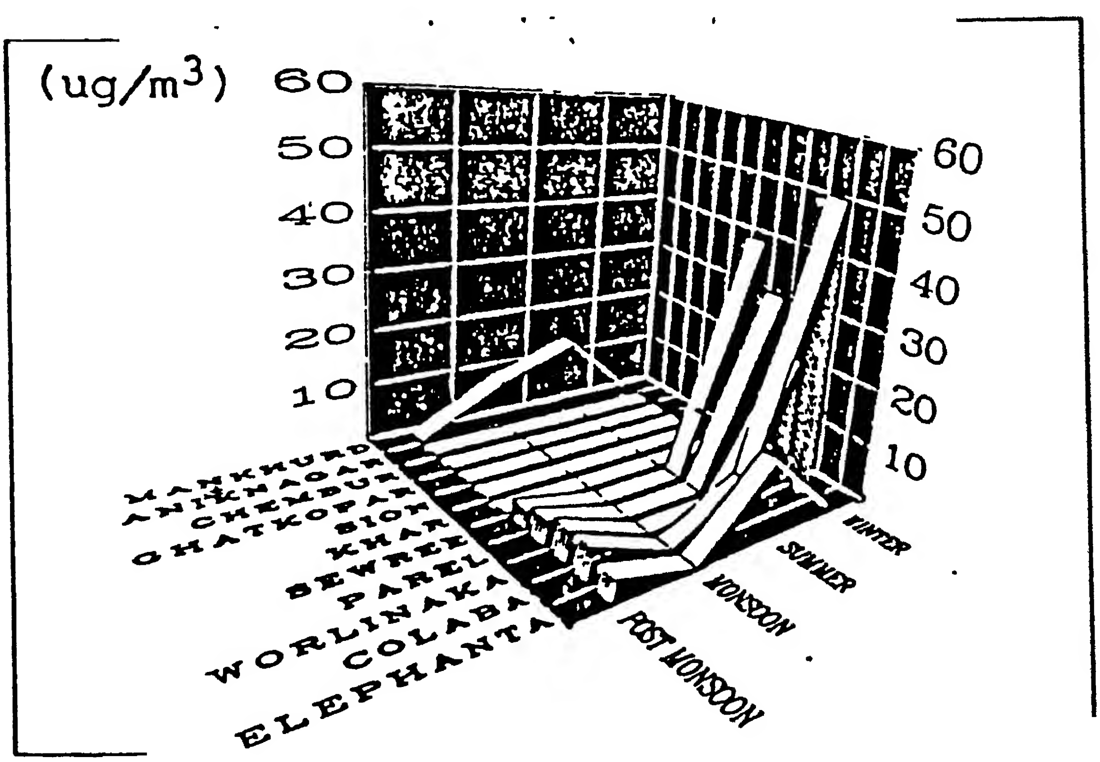

Fig. 3. Seasonal 95 percentile NO_x levels from a power plant.

The dry disposal system transports and deposits the waste in the landfill as a solid. Bottom ash is transported hydraulically to a dewatering bin or pond, flyash is collected in silos for transport to the disposal site. They are generally transported and disposed separately. Ash is typically trucked to the landfill, dumped, spread and compacted with the use of water. Advantages of dry disposal techniques lie in a lower requirement for land and water and often lower capital costs Control of leachates and ground water protection is easier. Site closure and revegetation is simpler and cheaper. The primary disadvantages centre on greater quantities of dust, noise and traffic, and higher operating costs The most important positive aspect is the ease of reclamation in future use of ash

Due to the scarcity in land availability, the Ministry of Environment and Forests (Government of India) is asking for 100% ash utilisation Ash can be utilised in various ways, given below.

Ash Utilisation. The simplest application is as a filler material such as in the making of roads and backfilling of mines. A more 'value added' form is in the manufacture of bricks and cement However its economic viability is strongly dependant on various factors such as location, etc

Quantification of ash disposal: The range of ash disposal activities range from direct dumping in the river, ash pond disposal, dry ash disposal in landfill, to ash utilisation A value function curve for ash disposal would range from 0 to 10 for the above activities for the same order, i.e. very low (nearing 0) for direct dumping to very high (nearing 10) for ash utilisation

3.2.3 Water Pollution· Both thermal and chemical discharges are responsible for water pollution Thermal pollution of the water bodies occur with boiler blowdown and/or when condenser cooling occurs This could affect the aquatic system in a number of ways For some fish species, warmer water spells disaster in the form of increased mortality rates and increased susceptibility to disease. For some other species, warmer water could imply a higher metabolic rate which leads to shorter maturing periods and shorter reproduction cycles. This has implication on the food

system, as it requires an increased production of food to sustain as well. The cooling systems fall mainly into two categories, (i) Once through systems: These systems circulate water through the plant condensers and return it to the environment, and (ii) Closed cycle systems. These systems circulate water from the condenser to another device in which the flow is cooled, generally by evaporation to the atmosphere. Common used cooling devices are cooling towers, cooling ponds and spray systems.

Chemical discharges occur due to the following Blowdown from the water subsystems of a thermal power plant is required to control the build up of dissolved and suspended solids and thereby prevent scaling, corrosion and fouling. For regulatory purposes, the discharge streams from power plants are divided into several point source categories of a) cooling water, i e. once through and cooling tower blowdown, b) ash transport water, i.e fly ash and bottom ash transport water, c) metal cleaning wastes, d) low volume wastes, and e) material storage run offi e coal pile and ash pile run off. Once through cooling water systems frequently require addition of chemicals, usually chlorine to avoid biofouling. Discharge of this effluent has to be controlled to avoid adverse effects on aquatic life. Ash transport water containes total suspended solids, oil and grease, etc. which are generally cleaned in the settling pond. However, small amounts of these trace metals could be leached and require control if the receiving water body is approaching ambient water quality standards

Quantification of water pollution: This is rather difficult to quantify given the site-specificity of the data requirements which include (i) current discharge levels (of pollutants) from the plant, (ii) the current pollution levels of the receiving water body, (iii) the knowledge of mixing patterns of the pollutants, (iv) the impact of all pollutants on each of the species present in the water body. While steps (i) and (ii) can be easily computed/obtained, (iii) and (iv) are extremely difficult to determine. Again, the standards could be used as a reference against which deterioration can be determined.

3.2 Hydro

Building of a dam or formation of a reservoir leads to the submergence of large areas of land. The two major issues therefore are large scale displacement and rehabilitation of the people and loss of large areas of land under forest cover.

3.2.1 Large Scale Displacement. Displacement and consequently the rehabilitation of people from the land they have occupied for centuries is a daunting task. People are emotionally attached not only to the land but also to their lifestyles Although in recent years rehabilitation packages offered have been very liberal the implementation in terms of administration inefficiencies and corruption coupled with the large number of people that need to be rehabilitated, rehabilitation is seldom complete. This leads to a large degree of discontent amongst the oustees. Often lives can be severely affected as in the case of tribals who are displaced from their forest homeland and have to change their way of life. Therefore there are two features that need to be looked at in the design stage. One, ofcourse, is the rehabilitation package itself. Two, is the scale of displacement, because, if it appears unmanageable, then there are bound to be delays in the construction period due to protests, etc., which can completely alter the project economics

Quantification of displacement discontent: For both the above issues, value function graphs would need to be drawn Rehabilitation packages would range from 0 to 10 starting from the worst to the best. Similarly, the scale of displacement would range from 0 (for large number of people displaced, say >100,000) to 10 (none, or a very small number of people displaced)

3 2 2 Forest Loss India's forest cover has depleted rapidly in the last few decades Currently less than 20% of the land is under forest cover against the governments' objective of 33%. Often, with the construction of a dam, large areas of forest are lost. Not only is the timber and other minor forest products lost but also environmental services like prevention of soil erosion, climate regulation, production of oxygen, absorption of carbon-dioxide and most importantly a provision of a habitat for birds and animals. In addition, tribals and other communities have their lives deeply woven around forests. Therefore this is a major issue and should be included in the evaluation

Quantification of Forest loss: This is difficult to quantify The scale would be similar to the scale of displacement graph, i.e. 0 for large forest loss and 10 for no forest loss

3 2 3 Others There could be other impacts, such as siltation, diseases (malaria, encephalitis, schistosomiasis, Fluorosis, etc), and risk of enhanced earthquakes in the area Althouh these are of relatively less importance than the two major issues, value function graphs can be made for each impact.

3.3 Nuclear

The setting up of a nuclear plant may pose radiological dangers to the local population in the form of low level radiation, surface and ground water radio-active contamination, and from waste disposal at plant site. As part of the plant design radioactive discharges are kept much below threshold (safe) levels, and therefore based on design operating features, the normal operation of a nuclear plant will cause no radiological threat to the neighbouring population and countryside. However, in the event of an accident (due to internal or external causes) a large release of radioactivity may result in catastrophic consequences. Non radiological threat includes 'thermal cooling' of the type described in the case of coal plants but with a higher degree of magnitude

Finalising the EIA: Value function graphs provide a way of quantifying the major impacts These impacts need to be weighted in terms of their relative importance. Since this is a value judgement, the value assigned is arrived at by conducting a survey The sample group needs to be carefully chosen over the cross-section of society It is important that the representative sample be truly representative of the population, and not just the policy makers. This will ensure the value of the weights are unbiased towards any group and therefore would reflect an objective result. Issues such as displacement would probably attract a wide range of values, and it is this difference in perception that is reflected in agitations and protests against some major hydro projects. Once the weight and scores are all obtained, the EIU with and without the power plant can be calculated. If the result is positive then the setting up of the power plant is environmentally acceptable.

3.4 Capacity Building/ infrastructural aspects

As seen from the methodology section, EIA requires large amount of data - meteorological, ecological and socio-economic. To elaborate, unless good meteorological data of the site is available, the dispersion of pollutants cannot be studied. Although, current requirements of an EIA in India include information on meteorological variables on a four season basis, a one year sample may not be robust. Similarly, data on flora fauna needs to be documented Therefore if EIA studies have to be conducted, the above data-bases need to be developed and **disseminated** Currently, in India there is some data that is being collected by individual organisations However there is no mandate for dissemination and therefore obtaining data, a basic prerequisite for EIA, becomes exceedingly difficult, resulting in EIA's that carry very little useful content What perhaps is also required is a central depository of EIA reports, where information on the various sites can be obtained from previous EIA studies. Often, there are a number of EIAs being conducted in a industrial estate, and all of them are conducting monitoring studies in the same area. This is extremely wasteful in terms of time and skilled resources.

For power plants in urban/stressed areas, a regional approach to EIA must be adopted In such areas, all polluting sources such as transportation, industries, etc, need to be looked at in a unified common framework This would help in determining least cost pollution control strategies, based on the marginal costs of all the pollution control technologies for all the options

Lastly, EIA is a resource consuming task, and therefore the focus must be on minimising the effort (without diluting the output) One way is to zone the country based on the levels of stress For eg. in many rural sites putting up a thermal power plant may not cause high air pollution (keeping ofcourse the mandatory pollution equipments) and perhaps if ash handling is taken care of, a rapid EIA (completed in 3 months should be adequate). Similarly, guidelines on the amount of forest loss and the number of displaced people should govern the design of hydel projects such that these aspects are taken care of during the design stage

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Environmental Implications of Energy Use in the Transport Sector

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Energy in Transport: Issues and Options for Sustainable Mobility Futures

Introduction

Personal mobility and the timely movement of goods are becoming increasingly important in all developing countries, and energy use for transportation is growing rapidly as a consequence Figure 1 shows the close relationship between economic development and passenger and freight transport growth in selected countries, and indicates the potential for rapid increases in transport demand in India over the next few decades [1] The bulk of transport energy requirements in India have traditionally been met by petroleum products (principally petrol and diesel), and the share of petroleum in the transport-sector energy mix has been steadily rising Figure 2 shows the growth in consumption of the two principal energy sources (petroleum and electricity) in the various transport modes, it is evident that the growth of petroleum use in road transport is increasing extremely rapidly

This rapid increase constitutes the largest single source of increase in the petroleum requirements if the country, (transport accounts for about 50% of oil consumption in India) and in the consequent need to import petroleum and petroleum products Petroleum imports currently (in 1992-93) account for over 27% of total imports, which, in turn implies a net outflow of about 2 5% of the GDP (as compared to 1 2% in 1988-89)[3]

The second issue related to increased petroleum use for road transport is the associated increase in emissions, and the impact on the urban environment The air in Indian cities is now amongst the dirtiest in the world [4] and transport emissions account for over two-thirds of the airbome pollutants in major Indian cities [e g 5,6]

In assessing these trends and issues, it is important to point out that energy is not required for its own sake it is utilized to power mobility Society requires and demands mobility, and energy consumption is consequent to that demand It is therefore necessary to view energy issues from the perspective of changing mobility needs and trends

Mobility Trends and Energy Demand

There are three major transport service requirements each with its own determinants There are urban (passenger) transport, intercity passenger transport, and (intercity) freight transport Each of these requirements are met by a variety of modes, each with a characteristic energy consumption pattern

Table 1 presents estimates of growth in motorized road and rail traffic over the past decade The shift in the modal split in freight transport is important Composite all-India urban transport estimates over this period are not available, it is estimated that the 1990-91 demand was 335 billion passenger-kms [7] In addition to the urban motorized road traffic, bicycles contribute a significant share of the transport service in urban areas Various

FIGURE 2: Specific fuel consumption of different transportation modes

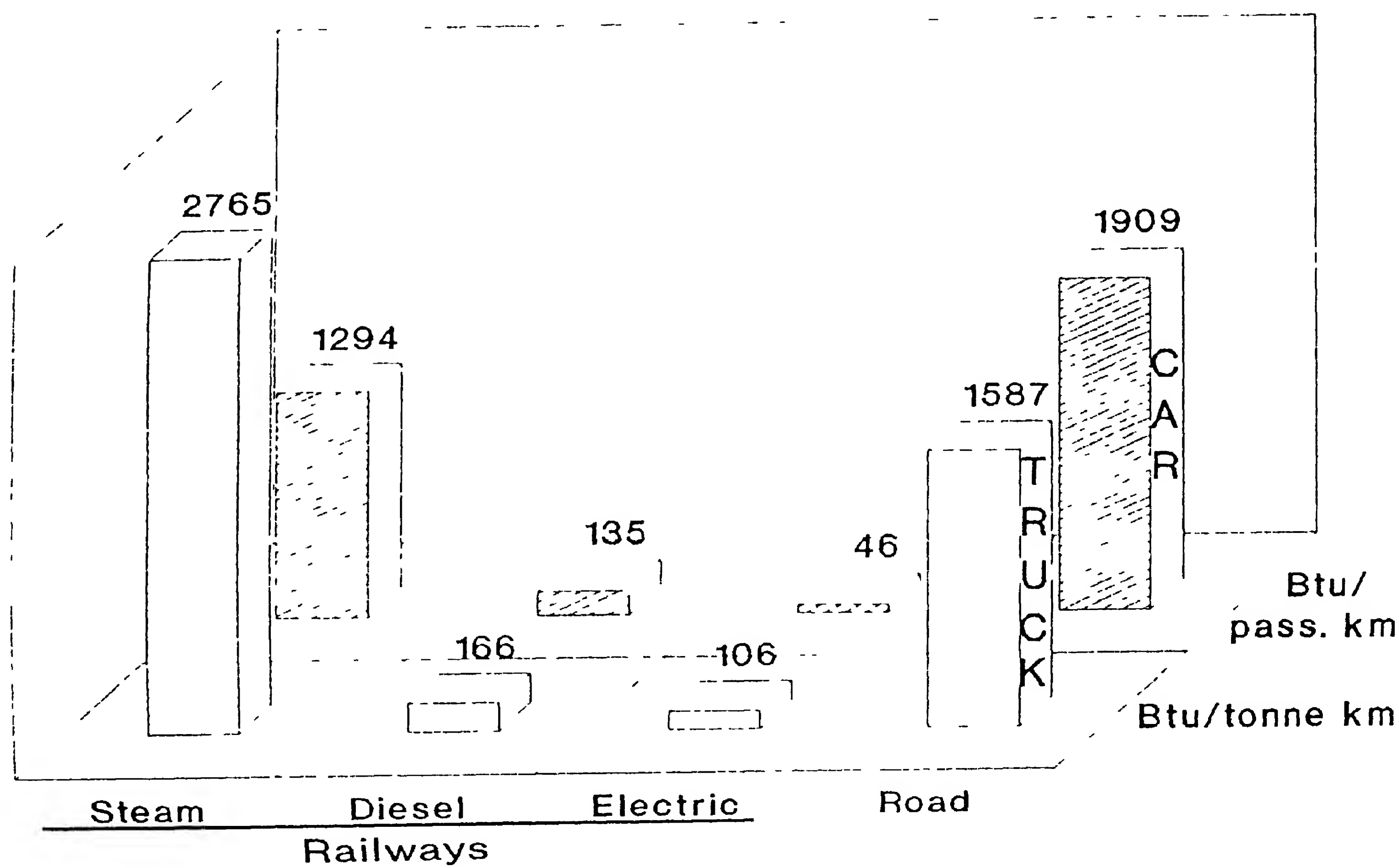
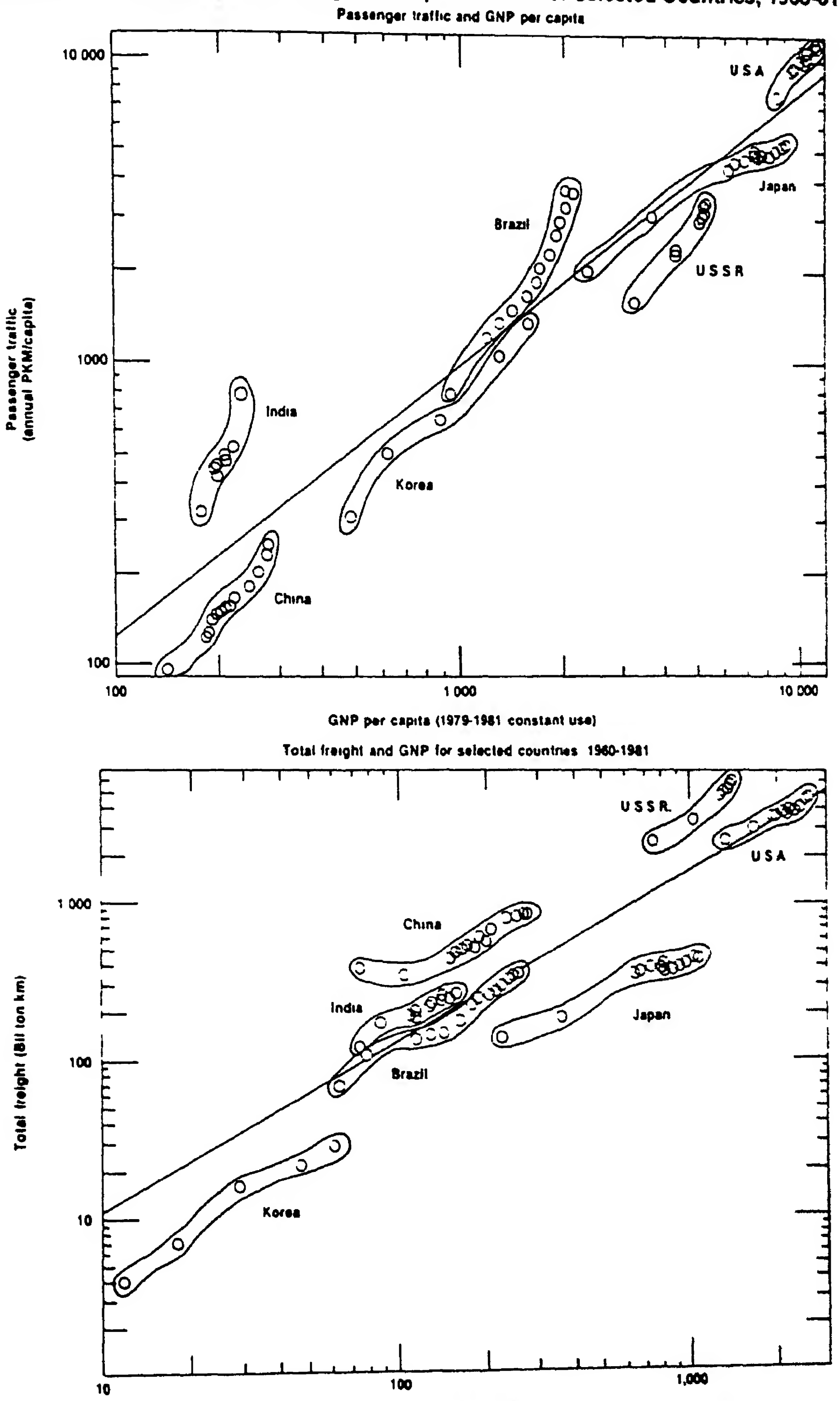


Figure 1: -Passenger and Freight Transport v. GNP for Selected Countries, 1960-81



This figure shows how passenger and freight transport energy use have increased with GNP for seven countries. The individual data points are for specific years

SOURCE J Venny and L Uy, "Transport in China," World Bank staff working paper, No. 723, Washington, DC, 1985.

surveys have indicated that cycles and cycle rickshaws contribute 20 to 50% of the total trips in Indian cities [8] In fact, the cycle is the most widely owned means of transport, with over 60% of households have access to atleast one cycle [9] This implies minimum ownership levels of 150 cycles per 1000 population Table 2 shows the growth of motorized vehicles in India It is important to note the personalized means of transport have grown much faster than mass transport vehicles (principally buses)

Table 1: Growth in Transport Demand in India

	RAIL			ROAD	
	Passenger		Freight	Freight	Passenger
	Urban	Intercity			
1972-73				59	309
1973-74			122	63	295
1974-75				64	327
1975-76				73	353
1976-77				75	358
1977-78			163	84	377
1978-79				92	396
1979-80			156	84	427
1980-81	41	167	158	98	451
1981-82	44	177	174	103	514
1982-83	46	181	178	106	554
1983-84	42	181	178	124	597
1984-85	44	182	182	131	651
1985-86	45	195	206	140	732
1986-87	48	208	223	149	764
1987-88	52	218	231	160	812
1988-89	52	212	230	188	913
1989-90	55	226	237	206	1008
1990-91	60	236	243	223	1136
1991-92	63	251	257	227	1221

Passenger transport is in billion passenger-km, and freight transport is in billion tonne-km

Table 2 : Registered Motor Vehicle

Year (as on 31st March)	All Vehicles	Two Wheelers	Cars, Jeeps and Taxis	Buses	Goods @ Vehicles	Others
1951	306	27	159	34	82	4
1956	426	41	203	47	119	16
1961	665	88	310	57	168	42
1966	1,099	226	456	73	259	85
1971	1,865	576	682	94	343	170
1972	2,045	656	740	100	364	185
1973	2,109	734	709	95	308	263
1974	2,327	838	768	105	323	293
1975	2,472	946	766	114	335	311
1976	2,700	1,057	779	115	351	398
1977	3,260	1,415	878	119	383	465
1978	3,614	1,618	919	124	403	550
1979	4,059	1,888	996	133	444	598
1980	4,521	2,117	1,059	140	478	732
1981	5,336	2,599	1,147	159	542	889
1982	5,997	3,043	1,230	170	601	953
1983	6,905	3,626	1,370	181	662	1,066
1984	7,783	4,327	1,430	196	728	1,193
1985	9,097	5,149	1,589	219	808	1,332
1986	10,490	6,207	1,758	223	848	1,454
1987	12,539	7,703	1,990	241	971	1,634
1988	14,733	9,257	2,279	266	1,101	1,830
1989	16,920	10,965	2,486	278	1,180	2,011
1990 (P)	19,117	12,531	2,736	313	1,290	2,306
1991 (P)	21,310	14,047	3,013	333	1,411	2,506
1992 (E)	22,583	15,026	3,130	341	1,425	2,661

Note @ *Excludes Three Wheelers*
(P) Provisional
(E) Estimated

Figure 3 presents comparative estimates of the commercial energy consumption in the motorized modes of transport, walking and bicycles do not appear in Figure 3 as they do not use commercial energy

Economizing Energy in the Transport Sector

Reducing transport demand Transport has aspects of quantity and quality, each with its own cost The simplest response to higher costs is a reduction in demand for transport as such less quantity at constant quality Some such response has been observed each time after increases in fuel prices or of rail transport prices However, substantial changes of this kind can only be expected to occur in the longer run The reason is that the

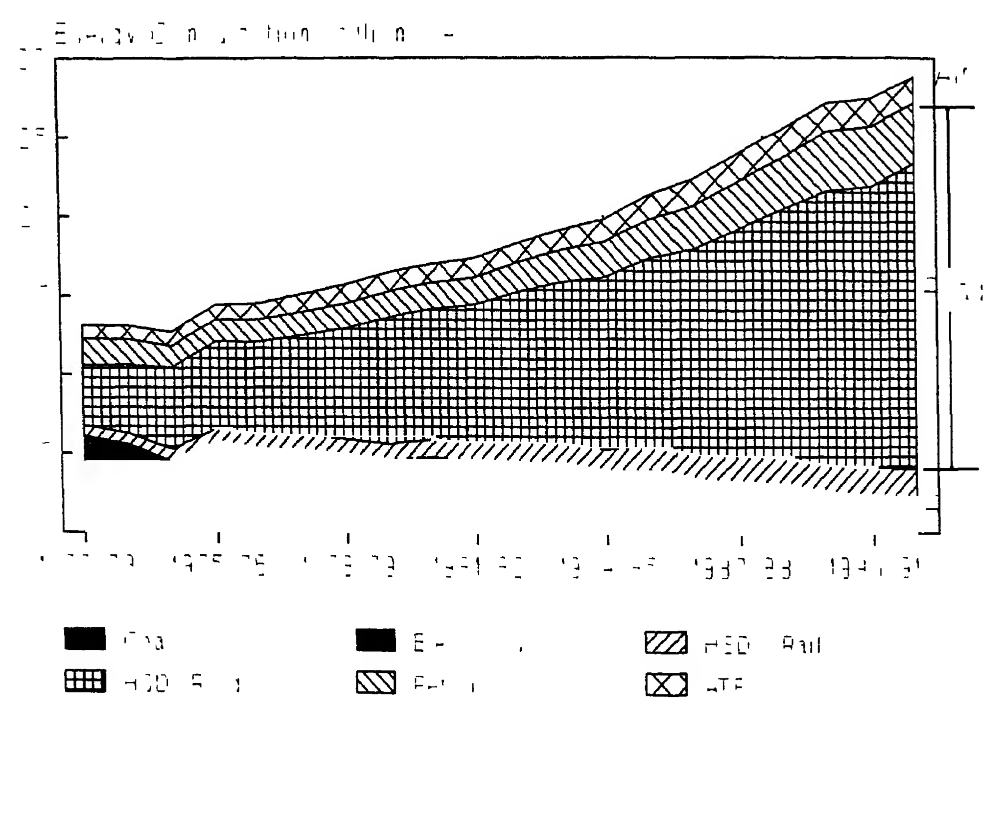


Figure 3 *Growth in the consumption of various energy forms in the major transport modes*

responsiveness of demand to changes in the price of transport is determined by factors such as relative location of production and consumption, and these are slow to change The entire response in the short run has thus to come from the effect of higher transport price on real income or quantity of output Changing landuse patterns which result in changes in residential location relative to place of work are thought to be easier to accomplish than changes in the location of production Consequently, price increase cause reductions in quantity to occur most readily in personal travel

Raising energy efficiency Many of the attainable improvements in energy efficiency imply a reduction in the quality, such as frequency, speed and convenience of transport services, but not necessarily in their quantity (in passenger-km or freight ton-km) There are two sources from which increases in energy efficiency may be expected shifts of traffic from less to more energy-efficient modes, and improvements within modes.

Changing the modal mix Different modes of transport possess on average, very different energy efficiency Per ton-km of traffic actually carried, for instance, (diesel of electric) rail requires roughly 3 to 4 grams of oil equivalent (goe) while road transport requires something like 40 goe River transport is relatively energy-efficient, air transport least so Nevertheless, drastic substitution between modes is not inevitable as a result of higher costs Shippers and passengers differ appreciably in what type of transport service they want and are willing to pay for, and will themselves change their preferences according to the needs of the particular movement envisaged There are many items in generalized transport cost, which includes costs falling on passengers or shippers, besides the cost of energy Second, modes differ much in their operating efficiency, with rail normally lagging behind road and air Some of the modal shift towards road in freight transport may have deserted the railways because of certain typical inefficiencies, such as delays, weak security, and inefficient claims procedures

Rising relative prices of energy should enhance the economic prospects of multimodal transport (for instance, inland water and truck, or rail and truck) relative to movements by single modes of low energy efficiency Multimodal transport requires for its development not only traffic suitable in density and direction but also new forms of terminal facilities, developments in commercial organization and in institutions Some of these developments will also raise the efficiency, and the energy efficiency, of individual modes, for instance through the creation of common-user truck terminals

The major user of energy among the transport modes is road transport, its share historically being between 65% and 80% of all energy used for transport The scope for intermodal substitution being limited in the short run, it will be the response of road transport which should determine the overall energy consumption and energy-use efficiency

Economizing energy in road transport The response of the road transport sector is limited by what is technically feasible It depends further on the incentives for using this scope and this is a matter of government policy Road users, acting on their own, can and will vary the method of operating their vehicles but there are other potential sources of economy which require supplementary action by government, local transport or highway authority, whether by way of changing regulations, altering taxes and duties, controlling congestion or investing in infrastructure

Economical driving and operating methods Experiments in the USA and Europe show that energy saving of the order of 20% should be attainable by appropriate changes in driving and operating methods The saving is obtained by keeping engine speed below 2,000 revolutions per minute, maintaining a constant traffic speed around 55 miles per hour, minimizing gear shifts and turning off engines whenever possible. It requires further that

engines are maintained through regular air filter changes, competent and timely tuning and the use of high quality lubricants

Reducing traffic congestion Congestion affects fuel consumption by forcing down the speed of traffic flow and by requiring frequent changes in speed and associated gear changes Recent research suggests that congestion on freeways in developed countries is capable of raising fuel consumption by as much as 50% The control of congestion has been pursued with success by a variety of policies from simple lane markings on roads to bus lanes, zoning combined with pricing, the introduction of parking lots and high parking fees, parking meters, improved traffic light systems, and other measures of traffic management.

This is especially relevant in Indian cities where the share of non-motorized traffic is high Mixed traffic leads to a greater number of starts and stops (and hence to higher fuel consumption/km and more emissions/km), as well as to an increase in road traffic crashes It is essential to redesign and replan traffic infrastructure to meet the demands of non-motorized traffic in order to enhance the energy efficiency of motorized road transport modes

Intensifying fleet use Savings of energy of the order of 5% or more appear possible through measures which raise the load factor of trucks This tends to occur, for instance, when common carrier services, which have been hampered by the taxation and licensing system are enabled to take over more traffic from own-account transport The construction of terminals and the extension of telecommunications can also contribute by permitting improved scheduling Some of these measure will induce not merely increases in average vehicle loads, but also increases in the size and weights of trucks and buses Energy is saved by performing a given volume of haulage by larger vehicles because the fuel requirement rises in a lesser proportion than weight

Energy-efficient vehicles Cars of the latest available vintage are some 30% more energy-efficient than the older models of cars in the country The difference in energy efficiency in trucks is of the order of 10-20% and more progress is expected The new generation of vehicles save energy by reductions in weight, better aerodynamics and efficient engines

In the case of two-wheelers, the new models are at least 20% more efficient than the older (pre-1985) models However, as almost all two-wheelers are fitted with two-stroke engines, unburnt fuel and emission levels are high Higher-efficiency two-stroke engines (with fuel injection) are required

Urban buses in India are built on the chassis of freight trucks, and have low energy efficiency because of their low speeds and oversized engines New models of urban buses, designed for the appropriate service and operating requirements, have to be introduced

Infrastructure improvement No quantitatively strong relationship has been established between variations in road roughness and fuel consumption However, the

rehabilitation and paving of roads and highways and corrections of road alignment and bends permit driving closer to least energy speed

Separate lanes for non-motorized traffic, priority lanes and signals for buses (which would also tend to promote modal shift to the more efficient transport mode), and enabling multimodal urban transport (through bicycle stands at large bus terminals etc) are essential

Alternative sources of energy The most promising alternatives to gasoline and diesel fuel are liquified petroleum gas (LPG), compressed natural gas (CNG), ethanol from sugar cane and methanol derived from gas LPG is already used, and CNG has been introduced in three cities The major issue in alternative fuels is the cost of infrastructure and of the opportunity cost of the resources that are required for alternate fuel production

In conclusion, an improvement of energy efficiency in road transport of the order of 30% over the next five years lies not merely in the range of what is technically feasible but should also be economically feasible The chief sources of improvement will be the use of more energy-efficient vehicles, and adaptations in the methods of driving, maintaining and managing vehicles, and from redesigning and replanning the urban transport infrastructure to integrate non-motorized transport

The Required Measures

Incentives The efficiency of operational decisions depends on the incentives facing those who have to make them Incentives are thus generally accepted as necessary to make private choices consistent with social objectives Operators also obey other sorts of signals, such as orders or restrictions However, it is important to avoid conflict between incentives and other signals If operators are to act so as to minimize energy use in transport, they must be presented with incentives which lead in that direction

Pricing and taxing The Government has, as a rule, determined the prices at which fuels are sold The diesel prices have always been below the level which would reflect international prices and an appropriate charge for vehicle use of the infrastructure

In setting fuel prices, a clean and transparent distinction between costs and taxes or subsidies is essential Costs are made up of the opportunity cost of the fuel, to be determined on prevailing border prices (or border prices and refining cost) and the cost of internal distribution They further include infrastructure cost (such as marginal road track cost) to the extent that this is charged to users on the base of fuels This cost represents what the country has to sacrifice in resources for another unit of transport. Price should not fall below it

If relative prices of substitute fuels are moved out of line with costs, substitutions will occur. Relatively low prices for diesel fuel or LPG have encouraged conversions and replacements of engines and vehicles at a cost which would not have been incurred if the prices had equalled costs The substitution is therefore uneconomic and since it requires investments the effects will be long-lasting

Regulation Steps need to be taken to reduce or eliminate the many forms of regulation (often combined with fees) with artificially lower the energy efficiency of transport. In road transport of freight, licensing requirements imposed on public carriers should be reduced. Larger vehicles should be made to pay for the pavement damage which they cause but there is no reason to restrict them further by licensing rules or taxation The suppression of competition on public (passenger) transport reduces the attraction to potential passengers and encourages travel by cars, at an unnecessarily higher cost in fuel per passenger mile Recent experience in Delhi indicates that competition in bus service leads to greater comfort and reliability An associated issue is that of safety - planning for a greater number of buses on the roads must be accompanied by appropriate traffic management techniques

Organizational bottlenecks Energy efficiency is an element in the comparative advantage of different transport modes but these economic and technical comparative advantages are muffled and partly falsified by organizational inadequacies Weaknesses in management, whether technical or commercial, and a variety of state interventions keep costs higher and revenues lower than necessary, in railways, and urban transport organizations Higher energy prices have raised the prospective return to organization improvement

Institutional barriers State institutions like the Customs and exclusive rights granted to organizations like ports and railways hinder the development of new forms of transport, such as container transport and inter-modal movements, which would lower transport cost With higher energy prices the case for review and reform is reinforced

Congestion. While higher fuel costs should have reduced urban traffic congestion somewhat, the economic pressure for increased mobility is leading to increase congestion The cost of transport, relative to the value it yields, can be reduced directly by measures to control and reduce congestion a substantial arsenal of internationally tested measures is available

Information, education and research There is need to establish a network of research and consultancy organizations that collect information on energy-efficient methods of operating and maintaining vehicles, test the validity of the methods under Indian conditions, and disseminate the information by publications and training courses Training and exams for obtaining driving licenses should include emphasis on fuel-saving driving practices Tests of the energy efficiency of different vehicles and engines and the properties of alternative fuels and lubricants under local conditions should be encouraged in technological research establishment

Conclusions

The transport sector does offer considerable potential for energy efficiency improvement However, it is vital to remember that the objective is not only to save energy, but more importantly to develop least-cost solutions to satisfy transport demand, that most of the fuel consumption is by a multitude of small users, and that energy efficiency is closely related to the overall efficiency of the transport system

To lay the foundation for preparing, and subsequently monitoring an action programmes for energy efficiency in the transport sector, more attention needs to be given by governmental agencies to systems for gathering the more specific data on fuel consumption and use of transport that is now needed For instance, information needs to be collected, on a sustained basis, about the use of fuels by different modes, energy efficiency in actual operations, and the extent of use of fuels and transport modes by different productive sectors, regions and income-classes

In the preparation of programmes to achieve greater energy efficiency in the transport sector, five broad areas of possible action require consideration First, existing transport investment programmes need review to ensure that they give enough attention to the modes such as railways (for dense traffic routes), river transport and coastal shipping (whose potential has been neglected in India in recent times, but is somewhat enhanced by the increased cost of energy), and that appropriate modifications have been made to design practices and standards, especially in the highway field and in urban infrastructure design (particularly to account for the needs of non-motorized traffic) Second, government intervention in the transport sector needs re-examination, to ensure that fuel pricing and taxation is appropriate, and to identify reforms in regulatory, licensing and vehicle-taxation arrangements that could increase the efficiency of operation of the transport system Third, there may be scope for formulating new types of investment projects which have become worthwhile partly or largely because of the increased cost of energy e g , training management improvements, upgrading of vehicle maintenance facilities, and intermodal projects Fourth, potentials for developing domestic sources of fuel need examination, including non-conventional fuels, the use of which by the transport sector may require some adaptation of vehicles, servicing facilities, etc Fifth, the desirability of undertaking technical or economic research in the country on matters related to the use of energy in transport should be considered

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PATTERNS OF DAILY EXPOSURE TO TSP AND CO IN THE GARHWAL HIMALAYA

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Abstract—Daily integrated exposure to TSP and CO was assessed by personal and stationary sampling of air in six microenvironments Time-budget surveys were conducted to determine how much time four population groups (adult women, children, adult men and youths) spend in these microenvironments Burning of biofuels in traditional unvented cookstoves is the most important anthropogenic source of pollutants in the study area—a rural and hilly region in the Garhwal Himalaya.

Concentrations of pollutants measured at the time of cooking were found to be very high but comparable to those measured in the Indian plains (5 6 mg m^{-3} and 21 ppm for TSP and CO, respectively). The daily exposure of adult women to TSP and CO was estimated to be 37 mg h m^{-3} and 110 ppm h, respectively Daily exposure, within each of the four population groups, was found to be very uniform across individuals for both the pollutants Patterns of concentrations and daily exposure, as influenced by the time of the day, season and altitude are discussed

Key word index Biofuel combustion, time budgets, microenvironments, daily exposure, personal sampling, developing countries, cookstoves, TSP, CO, Himalaya

INTRODUCTION

It is estimated that in 1990, 72% of India's population was rural based Economic development has brought modern technology, especially new sources of energy, to these rural communities, but the extent to which these technologies have spread is insignificant Even in regions where advanced technology is being used for agriculture, energy use in the household sector remains traditional These communities are characterized by an extensive and almost exclusive use of biofuels in traditional cooking and space heating devices A significant fraction, 43% (Natrajan, 1985), of the urban population, especially the lowest income category, also uses such fuels and devices to meet its energy requirements

Combustion of these fuels occurs in devices that have low thermal efficiencies and high emission factors, and which are largely without flues (Ahuja *et al*., 1987) Combined with the poor ventilation of the houses in which they are used, the situation has the potential to produce very high concentrations of air pollutants Adult women in rural India, who constitute about 30% of its rural population, are therefore the group with the highest risk, as they are the ones who do the cooking. Young children (about 12% of the rural population), who are often by their mother's side when she cooks, are also a high-risk group

Though a fairly reliable estimate can be made of the number of people who are likely to be exposed to such smoke, it has still not been widely established whether all of them would be subjected to a similar range of concentrations of pollutants Only a few studies have been conducted in India which examined this problem, Smith *et al* (1983), Patel *et al*. (1984), Ramakrishna (1988) and Menon (1988) These studies were mainly exploratory in nature. They attempted to experiment with different sampling techniques, identifying the characteristic pollutants and determining the effect of various geographical, climatic and socio-economic factors These studies confirmed that the levels of Total Suspended Particulates (TSP) and carbon monoxide (CO) in rural kitchens can reach exceedingly high values

It became obvious from these studies that cooking is the major activity that contributes to atmospheric pollution in rural areas However, the amount of pollutants in other microenvironments (such as living rooms, outdoors, etc.) and the time spent by individuals in these microenvironments have not been measured so far. While it is known that individuals in developed countries spend as much as 90% of their time indoors (Szalai, 1972), such data on rural people in developing countries are not available Cultural factors, traditional practices and climatic conditions would influence the time spent by people in smoky environments It would therefore be useful to determine the extent of differences in exposures of populations across regions in the country, owing to these factors

It was our intention to extend the earlier work by (a) measuring the concentrations of CO and TSP in a new geographical setting, (b) assessing the daily exposure to TSP and CO and (c) comparing the daily exposure of various groups of the population. The earlier studies in India were all restricted to the plains, stopped at measuring concentrations and focused only on adult women and children. This paper discusses the dis-

tribution of the concentrations of TSP and CO, the factors that affect the concentration and the distribution of daily exposure of four groups within the population. Throughout this paper concentration means the mass (or volume) of the pollutant per unit volume of air, and exposure means the product of concentration and time

DESCRIPTION OF THE REGION UNDER STUDY

The study was conducted in villages in the Pauri District of Garhwal Himalaya Garhwal lies in the central Himalayan region of north India The highest point in this district is 3100 m while the highest village is at 2500 m The area has subtemperate to temperate climate and has distinct seasons, unlike most of the areas in the Indian plains Subsistence agriculture is the main economic activity, with wheat, rice and maize as the major crops. There are also a few cottage industries. Trucks, buses and jeeps are the main modes of transport. The most common fuelwood species is 'Chir' Pine (*Pinus roxburghii*), found at altitudes of 900–2000 m. Another important species is 'Khank' (*Celtis australis*) found between 1300 and 2400 m Other common trees are 'Banj' Oak (*Quercus leucotrichophora*) and 'Burans' (*Rhododendron arboreum*), which grow above an altitude of 2000 m. A commonly used shrub, 'Tunga' (*Rhus parviflora*) is found at altitudes between 900 and 1500 m

Villages are clustered mainly on the gentle slopes of the ridges on the fluvial terraces Villages have between 10 and 100 households The average family size is six A typical house has a kitchen and a cowshed forming the ground floor with two living rooms on the first floor Houses are constructed with stone, mud and wooden beams. The roofs are made of slate stone There is no gap between the walls and the roof Smoke from the kitchen, therefore, flows out only from windows and doors. Combustion of biomass is thus the major source of air pollutants, and most of this occurs indoors. A traditional two-port unvented clay stove is used for cooking. These stoves are shaped like a box (about 45 × 60 × 25 cm). The stove is placed on the floor in the kitchen Crop residues and leaves are burnt in open fields as a mode of waste disposal

STUDY DESIGN

The daily integrated individual exposure of four groups of the population—adult men, adult women, youths (6–18 years) and children (0–5 years) was assessed. The choice of groups was based on common activity patterns. The assessment involved measuring concentrations of TSP and CO in the more important microenvironments. These are six in number—the kitchen during cooking sessions, the kitchen during non-cooking sessions, the living room, outdoors in the vicinity of the village during cooking sessions, outdoors in the vicinity of the village during non-cooking sessions and outdoors (fields, etc), far away from the village This is not to imply that people of this region cook outdoors but it is anticipated that cooking indoors might release pollutants which leak into the ambient atmosphere In choosing these microenvironments we were guided by the principle that a microenvironment needs to be defined in time as well as space Microenvironments that were not covered include schools, market places, shops and vehicles. Whenever a reference was made to these latter microenvironments, a suitable surrogate was chosen from the former set of six microenvironments For example, the outdoor non-cooking microenvironment was substituted for the market place

TSP and CO concentrations in these microenvironments were measured using stationary samplers The only exception was personal sampling of TSP at the time of cooking, for this, the personal sampler was tied around the cook's waist In all but the cooking microenvironment, there being no known single strong point source of pollutants, stratification is not expected Therefore, stationary sampling in these microenvironments is a good approximation Pollutant concentrations were monitored during the three daily cooking sessions (breakfast, lunch and dinner). In the other five microenvironments monitoring was done twice a day—once in the morning and once in the afternoon. Monitoring was also repeated over three seasons monsoon (August 1989–October 1989), winter (November 1989–March 1990) and summer (April 1990–July 1990). We planned our visits to the villages to coincide with the peak of each season

Time-budget surveys were carried out to determine how much time each individual spends in each of the six microenvironments. These surveys were conducted twice, once in winter and once in summer In a given season, for a given pollutant, the daily integrated individual exposure was computed as follows

$$E_i = \sum_{j=1}^{6} c_{ij} t_{ij},$$

where E_i = the daily integrated exposure of the ith individual (mg h m^{-3} and ppm h for TSP and CO, respectively), c_{ij} = concentration of the pollutant in the jth microenvironment associated with the ith individual (mg m^{-3} and ppm for TSP and CO, respectively), t_{ij} = time spent by the ith individual in the jth microenvironment associated with him/her (h).

Here, $\Sigma_{j=1}^{6} t_{ij} = 24$ h for all i.

After having computed the E_is, the four group averages were computed

Experimental design

A complete factorial design (Cox, 1958) was used to investigate the effects of season, altitude and time of day Among the numerous factors that can affect the concentration of pollutants, we found it feasible to

consider only these three factors as "controlled" independent variables The other variables, such as those related to weather and cultural practices, were the "uncontrolled" independent variables of the experiment Three levels were chosen for each of these factors, as follows season—monsoon, winter and summer, altitude—910, 1400 and 1800 m, time of day—morning (5 to 11 a m), midday (11 a.m to 5 p m) and evening (5 to 9 p m). Of these three factors, season and time of day would be considered as treatment factors and altitude would be a classification factor The choice of three levels for each factor is justified on the basis that both the slope and curvature of the response surface are more precisely estimated from three equally spaced levels than from four or more equally spaced levels with the same extreme points (Cox, 1958) Random ordering of experiments was not feasible owing to logistical problems

The altitude factor was represented by choosing one village at each of the three altitudes mentioned above The only criterion used in selecting villages was that they be located far away from the road, to avoid interference from vehicular emissions and resuspended dust from dirt roads Only a few villages in this district are located along the roads Therefore this criterion would lead to the selection of representative villages

Household selection

Samples were selected in two stages In December 1988, a survey was conducted in the district to obtain a general picture of the region in terms of parameters such as stove types, fuel usage, house and kitchen characteristics, cooking practices and other possible sources of pollutants The survey covered 122 households in seven villages From these seven villages, we then chose Bhainswara (1800 m), Kadola (1400 m) and Kweerali (910 m) The difference in altitude of over 400 m, provided by the villages chosen, was deemed sufficient to investigate the effect of altitude Two important findings of this survey were (1) fuel is rarely used for the sole purpose of space heating and (2) crop residues, animal dung and kerosene are rarely used for cooking Other major findings are presented in Table 1 From this survey it was immediately apparent that for most of these parameters there is a widespread uniformity, both within a village and between villages This is not surprising because all villagers have a similar economic status and a narrow range of available resources Thus it was decided to choose only typical households for our study A typical household of this region has these characteristics fully protected kitchen located downstairs as a part of the house but not connected to any other room These kitchens, which have an average volume of 20 m³ (height 1 5 m), are not used for living purposes (From Table 1 it might appear that there is a significant fraction of households that have a kitchen located upstairs and households that have kitchens connected

Table 1 Household and kitchen characteristics

Village	Approx altitude (m)	No of hh*	Number of hh surveyed	Total population	Average family size	% of hh where the kitchen is located upstairs	% of hh where the kitchen is also used as living space	% of hh where the kitchen is attached to another room	% of kitchens which are partially protected	% kitchens with: Only TC†	TC and kerosene stove which is used often	TC and kerosene stove which is used rarely	TC and other types of stoves
Kolari	1600	~60	31	~380	6	29	13	39	3	26	16	26	32
Kadola‡	1400	12	12	69	6	0	0	33	0	0	58	0	42
Kandai	1700	12	12	83	7	42	17	50	8	25	25	50	0
Naugaon	1100	18	18	109	6	67	56	28	0	94	0	6	0
Bhainswara‡	1800	~70	18	400	5	28	6	22	0	44	28	28	0
Nakot	760	14	14	57	4	50	36	43	14	7	14	72	7
Kweerali‡	910	17	17	88	5	24	41	18	6	71	0	29	0
All villages	—	—		—	-	35	24	33	4	40	18	29	13

* hh: Households.
† TC. Traditional Chulha (stove)
‡ Villages selected for the study

to other rooms but this is primarily because of the contribution of the village Naugaon to the average The situation in this village is unique and cannot be taken as representative) Another justification for choosing typical households only was the observation in earlier studies (Ramakrishna, 1988, Boleij *et al* 1989) that there is a greater variation of pollutant levels within a household than between households of the same village A replication factor of four, i e four households in each village was decided upon from purely practical considerations, for experiments in the kitchen-cooking microenvironment At least in two of the selected villages this roughly corresponds to 25% of the population For experiments in other microenvironments a replication factor of two was chosen Available data about population parameters were too meagre to arrive at an appropriate sample size Within a village, households on a similar elevation were selected These households were chosen at random from a list of households that agreed to co-operate with the investigators and satisfied the household selection criteria described above Selecting four households in each of these three villages led to a sample of 70 individuals (17 women, 15 men, 29 youths and 9 children) The response rate was very satisfactory All the 12 households co-operated in all the three seasons

MEASUREMENTS

A personal air sampler Spectrex PAS3000, was used for TSP monitoring and a portable Ecolyzer model 211 sampler was used for CO monitoring The TSP sampler had a servo control to adjust for pressure drops At the time of cooking, the pump of the TSP sampler was attached to the waist of the cook, with the cassette (in closed face mode) pinned to the shoulder nearer the stove The flow rate of the TSP sampler was set to 2 ℓ min^{-1} The CO monitor (which gives instantaneous values) was placed 1 m away from the stove at a height of 60 cm above the floor (The nose is roughly at that height when a person is squatting on the floor) The sampling duration was made to coincide with the duration of cooking CO readings were recorded manually at 1-min intervals

For the other two indoor microenvironments, both instruments were placed in the centre of the room at a height of 91 cm (The nose is roughly at that height when a person is sitting on a low chair stool commonly used in this region) Sampling duration was set to 1 5 h For the two outdoor microenvironments in the village these samplers were placed at roughly the centre of the village In all outdoor experiments the samplers were placed at a height of 1 5 m and the sampling duration was set to 4 h The flow rate of the TSP sampler, for these five microenvironments, was set to 3 ℓ min^{-1} if the Spectrex PAS300 sampler was used and to 6 ℓ min^{-1} if the Casella AS808 was used

All samplers were checked and calibrated before and after every experiment For the CO monitor a 50 ppm span gas was used The soap bubble technique was used to measure the flow rate of TSP samplers If the difference between the initial and final flow rates was more than $\pm 10\%$ then that TSP sample was rejected

Whatman membrane filters of 0 8-μm pore size and 37-mm dia. were used. Filters were desiccated for 24 h with silica gel before weighing them in an electronic balance with an accuracy of 10 μg This was done in New Delhi As many filter cassette holders were taken to the field as the number of experiments to be performed, to avoid the risk of the dusty environment contaminating the filters if they were to be transferred from a container to the cassettes in the field One in every 25 filters was used as a field blank Corrections to the change in mass were made separately for each season

Other measurements included indoor and outdoor temperature and humidity (using a whirling psychrometer), atmospheric pressure wind speed and direction and type amount and moisture content of the fuel burnt (as applicable in each experiment) Attempts were made to determine the air exchange rates, wherever feasible, by examining CO decay rates

Special attention was given to designing a protocol for the monitoring of indoor cooking sessions, especially because the participants were not in a position to operate the instruments themselves This led to a situation where the investigators had to operate many instruments in the confines of the small kitchen where, apart from the cook there might have been a few more members of the family present We designed a protocol that ensured a smooth coordination between the investigators and the cook a minimum disturbance to the normal cooking practices and an efficient measurement of all the variables of interest This was achieved by first designing a protocol and pretesting it in March 1989 Mock sessions were conducted in all participating households and also in a village, Dhanawas, near Delhi giving us an idea of site conditions. From this experience it was decided to modify the original protocol by having two investigators, each with well-defined responsibilities The original single data sheet, which was designed based on categories of variables to be measured, was accordingly split into two and designed according to the sequence of operations to be carried out by each investigator The data sheet then served as an efficient checklist as well Only that information which was needed for a particular experiment was collected Otherwise, it was observed that both the cook and the investigators felt overburdened and could not concentrate on their primary tasks. Therefore information on basic household parameters and time budgets was gathered on other occasions. (Further details of the protocol and data sheet are too lengthy to be presented here and may be obtained from the authors)

The mock sessions also exposed the participants to the devices that were to be used the type of experiments that were to be performed and the role they were expected to play Once their initial curiosity was satisfied and the awkwardness of the situation surmounted, their behaviour was more normal when the actual monitoring began in the monsoon season This, in turn, led to less uncertainty in the data We feel this to be an important consideration when dealing with rural folk in developing countries

TIME-BUDGET SURVEY

Our approach to gathering data on activities–microenvironment–time spent was restricted by the fact that participants could not maintain their own diaries, owing to low literacy rates Interviewing the participants was then the only way to get the same information Four questionnaires were designed, one for each of the four groups (adult women, adult men, youths and children) The four questionnaires differed in the type of activities being considered. The questionnaires were administered twice—once in winter and once in summer It was considered inadvisable to obtain seasonal information in one attempt, as the memory of people is not reliable in this matter. The

questions were carefully framed to obtain only facts and not perceptions

Yet another approach involved asking the respondent to describe how he or she had spent the day, on the day they were interviewed This open-ended approach was more successful in accounting for the entire 24 h than the previous approach However, we could not collect adequate samples from this approach The first approach gave us an idea of a typical day in that season whereas the second approach yielded the description of a particular day in the season Data from each approach was then examined to gauge the significance of large deviations, if any, in what was reported. Time-budget surveys are time consuming (approximately 20 min per person in a season) and therefore we could interview the family members of only those households in which we had measured pollutants earlier

RESULTS

The unit response was complete as all households co-operated throughout the programme There was some item non-response mainly due to inclement weather, instrument malfunction and the practice of some households of not cooking certain meals in certain seasons Due to constraints of time, it had been our practice to first complete the monitoring of kitchens, during the three cooking sessions, in a village In the remaining time, efforts were made to complete at least one replication of the factorial design in the other five microenvironments This explains the reduced sample size in these five microenvironments as compared to the planned sample size

Missing data have not been substituted All analysis of variance procedures have been carried out using log-transformed dependent variables

TSP concentration

Summary statistics of TSP concentrations in the six microenvironments are shown in Table 2 The mean concentration in the indoor cooking microenvironment was at least an order of magnitude more than the mean concentration in the other five microenvironments From Table 2 it is seen that there is a tendency for most sample statistics to decrease from the first microenvironment to the sixth microenvironment A two-tailed *t*-test ($P < 0.005$) showed that the mean of any of the three indoor microenvironments was significantly different from the mean of any of the three outdoor microenvironments

An analysis of variance of the complete factorial design was done on the TSP concentrations in the kitchen–cooking microenvironment The effects of the three factors, namely season, altitude and time of day, were highly significant ($F = 9.4$, 11 and 19, respectively, $P < 0.001$) Together, the three factors and four interaction terms explained 43% of the total variance Mean concentration was the highest in winter (6.8 mg m^{-3}) followed by summer (5.4 mg m^{-3}) and monsoon (4.8 mg m^{-3}). Mean concentration was the highest during midday (8.3 mg m^{-3}) followed by night (4.9 mg m^{-3}) and morning (4.0 mg m^{-3}). There was no consistent increase or decrease in concentration with an increase in altitude Analysis of variance of the measurements made in the village Bhainswara showed that 17% of the total variance was attributed to differences between kitchens The corresponding figures for Kadola and Kweerali were 22 and 30%, respectively

Analysis of variance performed separately for each of the microenvironments labeled 2–5 in Table 2 showed only the factor 'season' to have a significant effect ($P < 0.005$). In each microenvironment the winter mean was the highest, followed by the summer and monsoon means.

Table 2 TSP concentrations in the six microenvironments (mg m^{-3})

	Microenvironment 1	2	3	4	5	6
Sample size	95	29	21	22	22	3
Minimum	0.55	0.14	0.10	0.00	0.01	0.06
5th percentile	1.0	0.17	0.11	0.00	0.02	—
50th percentile	4.8	0.60	0.43	0.22	0.16	—
95th percentile	14	2.9	2.2	1.1	0.76	—
Maximum	20	3.0	2.3	1.1	0.77	0.15
Mean	5.6	0.82	0.63	0.26	0.23	0.11
Coefficient of variation, %	68	84	91	100	96	46
Geometric mean	4.5	0.64	0.47	0.15	0.19	—
Geometric standard deviation	1.8	1.7	2.0	3.4	2.2	—

1 Kitchen during cooking sessions
2 Kitchen during non-cooking sessions.
3 Living room.
4 Outdoors in the village during cooking sessions.
5 Outdoors in the village during non-cooking session
6: Outdoors, far from village.

Table 3 CO concentrations in two microenvironments (ppm)

	Microenvironment 1		2
	TWA*	Inst †	
Sample size	100	8904	29
Minimum	1	0	0
5th percentile	4	1	0
50th percentile	15	12	2
95th percentile	67	59	26
Maximum	162	354	31
Mean	21	19	4
Coefficient of variation %	105	132	175
Geometric mean	15	10	4
Geometric standard deviation	2	3	2

1 Kitchen during cooking sessions
2 Kitchen during non-cooking sessions
*TWA Time-weighted average
†Inst. Instantaneous

CO *concentration*

Summary statistics of CO concentrations in two microenvironments are shown in Table 3 In the other four microenvironments the concentrations were below the detection limit of the instrument

An analysis of variance of the complete factorial design was done on the CO concentrations in the kitchen–cooking microenvironment Only the effect of the factor 'time of day' was highly significant ($F = 30$, $P < 0\ 001$). Together, the three factors and the four interaction terms explain 40% of the total variance Mean concentration was the highest in summer (27 ppm), followed by monsoon (20 ppm) and winter (16 ppm). The midday mean was the highest (37 ppm), followed by night (19 ppm) and morning (11 ppm) There was no consistent increase or decrease in concentration with an increase in altitude Analysis of variance of the measurements made in the village Bhainswara showed that 45% of the total variance was attributed to differences between kitchens The corresponding figure was 20% for both Kadola and Kweerali. We are unable to explain the comparatively high value for Bhainswara

Analysis of variance of measurements made in the kitchen during non-cooking sessions showed the factors 'season' and 'time of day' to have a significant effect ($P < 0\ 005$) The mean concentration was the highest in summer (6 ppm), followed by monsoon (4 ppm) and winter (3 ppm) In this microenvironment the morning mean (7 ppm) was higher than the afternoon mean (1 ppm)

The above discussion on the distribution of CO concentration relates to the time-weighted average in each measurement session. For the kitchen–cooking microenvironment the instantaneous CO concentrations from 100 sessions are summarized in Table 3 The log-transformed data shows a skewness of $-0\ 15$ While the mean of the time-weighted concentration and the instantaneous concentration are similar, the maximum values are significantly higher for the latter

Correlation between TSP and CO

Correlation analysis of the time-weighted average of the simultaneously measured TSP and CO concentrations during cooking sessions resulted in a coefficient, r, of 0 66 The coefficient has a two-tailed significance of $P < 0\ 001$

Daily exposure of adult women due to cooking

The daily exposure to TSP and CO was computed by summing the exposures during the three cooking sessions in each kitchen These exposures were in turn computed by taking the product of the concentration measured in a session and the duration of that session Results are summarized in Table 4

Time budgets

Figure 1 summarizes the results of the survey to study the time spent in a day in the six microenvironments Adult women spend 64 and 51% of their time indoors during winter and summer, respectively Adult men spend 48 and 34% of their time indoors during winter and summer, respectively Youths spend 49 and 43% of their time indoors during winter and summer, respectively Children spend 67% of their time indoors in both winter and summer

Daily integrated individual exposure to TSP and CO

For four groups of the population the daily integrated individual exposure was determined using the model mentioned earlier in the paper The results are summarized in Tables 5 and 6 for TSP and CO exposures, respectively It is seen that while the daily exposure to TSP is higher in winter than in summer for all the four groups, it is the other way around for CO Only the two kitchen microenvironments contribute to the daily integrated exposure to CO

To study the effect of each microenvironment the percentage contribution of each microenvironment to the daily integrated exposure to TSP was computed The results are summarized in Fig 2 For adult women cooking contributes the most to the daily exposure to TSP For adult men, youths and children it is the time spent in the living room that contributes most to the daily exposure to TSP For these three groups it is the greater percentage contribution of the living room in winter that leads to the daily exposure to TSP being higher in winter than in summer Agricultural activity contributes significantly to the daily exposure to TSP for adult men and youths in summer The long summer vacation enables youths to participate in kitchen chores. This explains why their exposure in the kitchen is higher in summer than in winter.

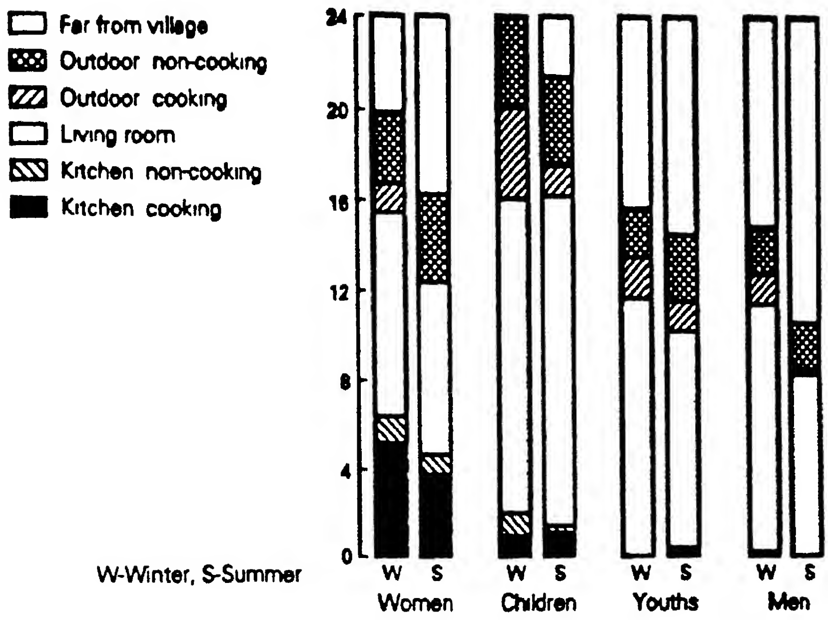

Fig 1 Mean time spent in a day in the six microenvironments (h).

Table 4 Measured daily exposure of women due to cooking

	CO (ppm h)	TSP ($mg\,h\,m^{-3}$)
N	36	36
Minimum	23	3 6
Maximum	248	35
Mean	69	17
Coefficient of variation, %	61	49
Geometric mean	60	15
Geometric standard deviation	2	1 7

There is one observation that is contrary to what was anticipated For adult women the daily exposure to TSP in the kitchen during non-cooking sessions is higher in summer than in winter The reason for this is unknown and further investigation is required

For all population groups the variation in daily exposure attributable to differences between households and individual differences was found to be insignificant.

Analysis of variance of the daily exposure to TSP showed that season and altitude had a significant effect ($P<0\,001$). But here again, as in the case of concentrations, no consistent trend is seen with increasing altitude These two factors had no effect on the daily exposure to CO

Relationship between measured and modelled daily exposure

The daily integrated individual exposure discussed in the preceding section has been arrived at using the model mentioned earlier in the paper Though concentrations were actually measured, the time budgets were reported values only But for one microenvironment, namely the kitchen–cooking microenvironment, the measured time data are available Using these, the daily exposure of women due to cooking was arrived at and the results were presented in Table 4

These results can be compared with the results of the model for the kitchen–cooking microenvironment For CO the actually measured mean daily exposure of women due to cooking is 69 ppm h, while the modelled mean exposure is 110 ppm h. For TSP the corresponding figures are 17 and 27 $mg\,h\,m^{-3}$, respectively On average, the modelled exposure is 1 5 times the measured exposure due to cooking. This is understandable when the discrepancy between the measured and the reported values of the average time spent in cooking per day are examined While the former value is 3 3 h the latter value is 4 5 h However, an overall reduction factor for the modelled value of the daily integrated individual exposure can be arrived at only if we know where individuals are overestimating and where they are underestimating the time they spend

DISCUSSION

The concentrations of TSP and CO measured in this hilly area during cooking sessions are in the same range (TSP 3–16 $mg\,m^{-3}$, CO: 6–51 ppm) as the concentrations measured by others in the Indian plains (Smith *et al*, 1983; Ramakrishna, 1988, Menon, 1988) Certain studies have been carried out in Nepal which, like Garhwal, is a hilly region (Reid *et al*., 1986, Davidson *et al*., 1986). TSP concentrations as measured in our study are comparable to those measured in Nepal (3–9 $mg\,m^{-3}$), but the CO concentrations

Table 5 Mean daily integrated exposure to TSP (mg h m⁻³)

	Adult women [17]*	Children [9]	Youths [29]	Adult men [15]
Winter	47	25	19	17
	(36)†	(51)	(44)	(46)
Summer	27	13	7 7	5 8
	(57)	(42)	(41)	(12)

*[ ] Number of members in the group
†( ) Coefficient of variation, %

Table 6 Mean daily integrated exposure to CO (ppm h)

	Adult women [17]*	Children [9]	Youths [29]	Adult men [15]
Winter	95	18	1	1
	(45)†	(39)	(400)	(300)
Summer	125	38	6	0
	(94)	(68)	(200)	(—)

*[ ] Number of members in the group
†( ) Coefficient of variation, %

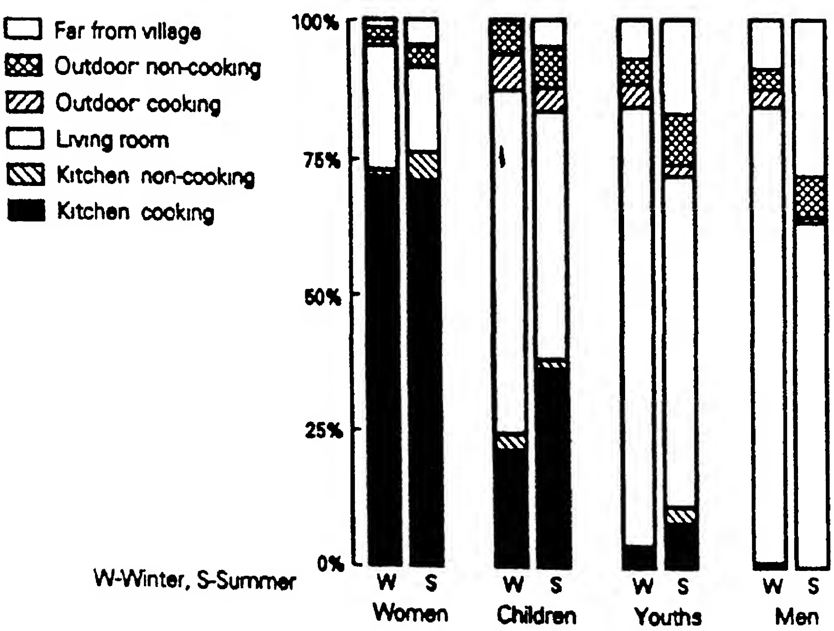

Fig 2 Mean percentage contribution of each microenvironment to the daily integrated exposure to TSP (%).

(40–240 ppm in Nepal) measured by us are less by at least an order of magnitude

Adult women spend some time in the kitchen during non-cooking hours, preparing for later meals or caring for the children. Mean concentration in this microenvironment was found to be significantly high for both TSP and CO. This may be due to poor ventilation, which in turn leads to low air exchange rates.

In the living room and outdoors, CO concentrations were found to be below the detection limit of our instruments. This suggests that CO has its source only in the combustion of biofuels and that CO which escapes the kitchen is quickly diluted TSP concentrations in the living room were, however, non-zero This may be due to infiltration of air from the kitchen and outdoors and resuspension of dust Indoor concentrations of TSP were higher than outdoor concentrations.

The variation in concentrations due to differences between households was much less than that due to

differences within households This indicates that we were successful in selecting similar households Since these households are typical of the region it is expected that concentrations are uniformly distributed across all households in the study area

Concentrations of TSP and CO are strongly influenced by the time of the day when the measurements were made Concentrations measured during midday were significantly higher than the evening and morning concentrations

Seasonal differences were more significant for TSP concentrations than for CO concentrations The pattern they followed was also different TSP concentrations in each microenvironment were highest in winter followed by summer and monsoon CO concentrations were highest in summer followed by monsoon and winter Our results are contrary to intuition, which suggests that concentrations would be the highest in cooler seasons (due to ventilation conditions and the longer duration of cooking) and in evening cooking sessions (again due to the longer duration of cooking) This paper only describes the patterns of concentrations and exposures, it is beyond its scope to provide valid explanations for these patterns However, in a future publication we wish to test the hypothesis that in this range of altitude, the inside and outside temperature and the difference between the two influences the concentration of pollutants Of course, quality of fuel may be another influencing factor

The results of this study are inconclusive regarding the effect of altitude on concentrations Though for TSP concentrations there was a significant effect of altitude, we did not observe a consistent increase or decrease in concentrations with increasing altitude Several species of fuelwood are available at any given altitude There is also a difference in available species at different altitudes Therefore, an experiment where the type of fuelwood is controlled may be more successful in determining the effect of altitude

The time-budget survey indicates that women and children are the only groups that stay indoors longer than they stay outdoors But even for these two groups the time spent indoors is significantly less than the time spent indoors by their counterparts in more developed societies In an agricultural society, such as the one which has been studied, such patterns are to be expected

The model for daily exposure to TSP used in this study predicts a range quite similar to that estimated by Smith (1987) (28 mg h m^{-3} for women and 14 mg h m^{-3} for others) based on studies in the Nepal hills (Davidson *et al*, 1986, Reid *et al*, 1986) Similar estimates by Smith based on studies in the Indian plains (Smith *et al*, 1983) are, compared to our results, higher for women (about 90 mg h m^{-3} annual average) and lower for other groups of the population (about 4 5 mg h m^{-3} annual average).

For all groups of the population, the indoor microenvironments contribute more to the daily integrated exposure than the outdoor microenvironments While for women it is cooking that contributes most to daily exposure, for other groups it is time spent in the living room which contributes the most

The daily integrated exposures to TSP and CO follow the same patterns as their respective concentration patterns with respect to season and altitude In any village, the variation in daily exposure due to individual differences within a group was only a small fraction of the total variance We had defined exposure as the product of concentration and time As discussed earlier the variation in concentration due to household differences was small Responses to the time-budget survey were highly uniform across individuals of a group This would then explain the uniformity in daily exposure across individuals of a group Whether the time-activity patterns are in fact uniform, or whether it is only the response to the survey questionnaire that is uniform, remains uncertain

A tendency was observed for individuals to overestimate the time spent in cooking This led to the estimated daily exposure due to cooking to be higher than the measured value by roughly a factor of 1 5 Better estimates of daily exposure would require either the use of 24-h personal sampling (which demands a great deal of co-operation from participants and infrastructure not readily available in villages) or detailed field observations of activity patterns (which demand considerable effort from the investigators)

In designing this study we were guided by past studies in the matter of measurement of concentrations For the first time a daily integrated exposure model has been used for rural areas in developing countries The uncertainties in time-budget surveys as discussed above are therefore of greater concern than the uncertainties associated with concentration measurements However, for the first time some estimates are available for the daily exposure to TSP and CO, showing again that adult women (over 19 years) and children (0–5 years) are at high risk It is now acknowledged that daily exposure is a better indicator of health risk than concentration (Smith, 1988). Yet, the uniformity in daily exposure across households and individuals within a group would suggest that unless intervention can create a subpopulation with significantly lower exposures, it will not be possible to establish the effects on health

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Time allocation study in three villages of the Garhwal Himalaya, India

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Abstract
Method of recall was used to study how people in Pauri district of Garhwal Himalaya allocate time to various tasks. Data on time spent in six important micro-environments was gathered. Comparisons across four population groups have been made. Results show that women spend more time in activities related to collection of fuelwood and fodder (four to six hours), compared to women in other areas. Domestic activities account for ten to twelve hours of a day. Time spent in cooking as measured by a stopwatch was considerably less than that reported by women through the questionnaire. Fuel usage patterns are also discussed.

Introduction

In the Garhwal Himalaya, like in most rural areas of developing countries, biomass continues to be the major source of domestic energy. It is likely that unrestricted harvesting of biomass will lead to a scarcity of resources and degradation of the local ecology. Yet, it is not clear to what extent domestic energy needs contribute to this in comparison with other causes such as: expansion of agricultural land, urban energy needs, etc. While attempting to evaluate, in a qualitative or quantitative manner, the relative contribution of the various causes, it is crucial to know the local people's perception of the problem. Time budget studies can help in identifying people's perception by examining the priority they attach to various tasks.

As a response to a perceived scarcity of fuel and/or ecological degradation, rural energy programmes have become very common in this region. Typically these programmes aim to conserve biomass resources by disseminating devices with greater efficiency and non-conventional technologies, encouraging the use of alternative fuels (biogas or commercial fuels) and increasing biomass production through scientific, managerial or organizational innovation. Very often these programmes fail to achieve their aims because they assume the following: a) surplus labour time, b) flexible routine of rural folk, and c) gender differences in the use of time are not of much consequence (Desai 1990). Here again, time allocation studies can help by testing the validity of such assumptions. These studies can be used to assess the feasibility of an intervention in the social and cultural contexts.

Lately there has been a growing concern that, over a long period, the harvesting, collection and use of biomass may affect the health of those involved in these

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tasks. Fetching heavy headloads of fuelwood and fodder over long distances and steep slopes is very strenuous. It may specially affect the health of women, who, for various reasons, consume comparatively less food than their male counterparts. Also, the combustion of low-grade biofuels occurs in traditional devices that have poor thermal efficiencies and, which are largely without flues. Exposure to smoke from such combustion is likely to cause respiratory illness in females and infants (Pandey *et al*, 1989). One may use clinical or epidemiological methods to measure such effects Still, as an approximation, the time spent in such activities is a fair indicator of the magnitude of the problem. As an example, a study used the time spent in cooking as a surrogate variable for exposure to pollutants. These researchers were attempting to correlate the burning of biofuels with the incidence of respiratory diseases (Pandey et al, 1987). Evidently, time allocation studies have a role to play in rural health studies as well

Studies were conducted in India and Nepal to obtain data related to time budgets of rural folk. These studies were mainly concerned with the implications of the data for planning rural energy programmes and development in general (Reddy *et al*, 1980, Acharya and Bennett, 1981). For such exercises in planning it is adequate to know how time is allocated for different tasks. However, certain health studies also may require to know how people distribute their time over space. That is, information is needed on how much time is spent on a particular activity and in which specific environment (Smith 1988).

We conducted a study in the Garhwal Himalaya to assess the daily exposure of females and other population groups to pollutants (Total Suspended Particulates and Carbon Monoxide) released during the combustion of biofuels. Such an exercise required measuring the concentration of these pollutants in all micro-environments that people of this region spend time in. In addition, the assessment procedure required estimates of how much time these population groups spend in these micro-environments. Typical micro-environments included kitchen, living room, fields, etc Results of the exposure assessment have been published elsewhere (Saksena et al, 1992) In this paper we wish to present results of the time allocation study.

The objectives of this paper are: (a) to estimate the time allocated to various tasks by four population groups in three seasons, and (b) to estimate the time spent in six important micro-environments by these four population groups in three seasons. In addition, fuel use patterns in the study villages are presented.

Description of the region under study

The study was conducted in villages in Pauri district of Garhwal Himalaya. Garhwal is in the Central Himalayan region of North India. The highest point in this district is 3098 m while the highest village is at 2480 m. The area has sub-temperate to temperate climate and has distinct seasons. Subsistence agriculture is the main economic activity, with wheat, rice and maize as the major crops. There are also a few cottage industries. Trucks, buses and jeeps are the main modes of transport. The most common fuelwood species is 'Chir' (*Pinus roxburghii*), found from an altitude of 900 m up to 2000 m Another important specie is 'Kharik' (*Celtis australis*) found between 1300 and 2400 m. Other common trees are 'Banj' (*Quercus leucotricophora*) and 'Burans' (*Rhododendron arboreum*), that grow above an altitude of 2000 m. A commonly used shrub, 'Tunga' (*Rhus parviflora*) is found at altitudes between 900 and 1500 m.

The 1981 national census survey yielded the following information about the district. The population density was 117 persons per square kilometer. The female population exceeded the male population. The average literacy in the district was 32%. While 59% of the males were literate, this was true only for 27% of the females.

The annual cropped area of the district was 21% of the total geographical area, including double cropping Dry farming prevails in the area In the district, 57% of the farmers had less than 2 ha of land, accounting for 20% of the agricultural land. The cattle density was 124 heads per square kilometer, 108 out of these were milch animals.

Villages in this district are clustered mainly on the gentle slopes of the ridges on the fluvial terraces. A village has between 10 to 100 households. The average family size is 6.

Sample selection and survey Methods

The selection of villages and the sample of households was based primarily on criteria related to the assessment of exposure to pollutants. These criteria, described in our earlier work (Saksena *et al* 1992), led to our selecting three villages and four households in each of them. Each individual of these households was interviewed. The sample size was, thus, 75 individuals (19 females, 18 males, 29 youths and 9 children). Preliminary visits were made to the selected villages between December 1988 and March 1990. During the stay in villages in this period we could identify the population groups to be studied, the various tasks that people engage in and the more important micro-environments. Four population groups were chosen: adult women,

adult men, youths (age 6-18 years) and children (age: 0-5 years). The choice of groups was based on our observation of common activity patterns.

The six micro-environments that we finally chose were: kitchen during cooking sessions, kitchen during non-cooking sessions, the living room, outdoors near the village during cooking sessions, outdoors near the village during non-cooking sessions and outdoors (fields, etc.), far away from the village. This is not to imply that people of this region cook outdoors, but it is anticipated that cooking indoors may release pollutants that leak into the ambient atmosphere. Micro-environments that were not covered include schools, market places, shops and vehicles. Whenever a reference was made to these latter micro-environments, a suitable surrogate was chosen from the former set of six micro-environments. For example, the outdoor non-cooking micro-environment was substituted for the marketplace. This limitation applies only to our estimates of the allocation of time over space Such substitution was not applied to the tasks carried out in these micro-environments

The choice of methods for time budget survey was restricted because most members of the population of this region are unable to maintain their diaries, owing to low literacy rates. We used a recall based questionnaire. Preliminary observations aided in the selection of elements to be included in the questionnaire Four questionnaires were designed, one for each group The questionnaires differed in the type of activities considered. The questionnaire was administered to each individual of the sample. The exception being the questionnaire relating to children, that was completed with the help of their mothers The questionnaires were administered thrice – in winter, summer and monsoon. It was considered inadvisable to obtain seasonal information in one attempt, as the memory of people is not reliable in this matter

Information gathered through the questionnaire was supplemented by asking respondents to describe how they had spent the day, on the day they were interviewed. This open-ended approach was more successful in accounting for the entire 24 hours than the structured questionnaire. However, we could not collect adequate samples from this approach While the questionnaire provided a description of a typical day in that season, the other approach yielded similar information for a particular day in the season. Where available, we compared estimates from both approaches and removed ambiguous responses. The actual time budget surveys were conducted in three seasons: winter (November 1989 - March 1990), Summer (April 1990 - July 1990) and monsoon (August 1990 - October 1990)

A limitation of our questionnaire is that it does not separately describe time allocation on week days, weekends and holidays. For males and youths, specially, making such a distinction between days of the week is necessary. Another, and

perhaps more important, limitation is the assumption that each task considered is performed daily in a season. This may not be true for some tasks, specially those related to agriculture and horticulture. These activities are either performed daily during a limited period within a season, or performed once every few days over the entire season.

We also measured time spent in cooking using a stopwatch. Data related to fuel usage patterns was obtained by measurement and observation.

Analysis and results

The data from time-budget surveys was compiled and was validated using the observations made. It was analysed to estimate the average time spent by the respondents in each population group in performing an activity. Analysis of variance was performed to understand the effect of altitude and season on time spent by different population groups in predominant activities. The measurements about time spent in cooking were correlated with those reported in the survey. The data on measured cooking time was further analysed to understand the effect of altitude, season, time of day and variation across households. For fuel use patterns, the data on the fuel mix, the percapita fuel consumption, burn rate and moisture content is analysed to understand the effect of altitude, season, time of day and family size.

Time allocated to various tasks: From Table 1, evidently, females of this region spend 10-12 hours of a day on domestic activities and 4-6 hours in activities related to collection of fuel and fodder. Of the 19 females in our sample, almost all reported that they took part in domestic activities. Caring for children was reported by 6, 5 and 8 females in monsoon, winter and summer respectively. Sixteen females reported that they collect fuelwood during winter. This activity in monsoon and summer was reported by 3 females. This may be because all efforts are directed towards agriculture in summer. In monsoon, the rains and damp would prevent females from collecting fuel. Sixteen females reported that they help in agricultural activities. The remaining females are much elder and therefore do not work in the fields. Only 6 females attended to their kitchen gardens. None of the females surveyed were employed. Only two females spent time in miscellaneous activities. Females of this region do not take cattle out for grazing. Their care of cattle is restricted to activities in the cattle shed. milking, cleaning, etc.

Of the 18 males only 7 were employed in nearby establishments. (Males who are employed elsewhere who do not reside in the village were not considered for this study). These males spend 8-9 hours travelling to their place of work and at work. The number of males who reported that they take cattle out for grazing was 11,12

and 9 in monsoon, winter and summer respectively. Working in the fields was reported by 5 and 15 males in winter and summer, respectively. As is clear, agricultural activities in summer prevent some males from taking their cattle out for grazing. Cattle are taken out for grazing in the morning and evening. Together, the time spent by males in attending to the cattle is 5-6 hours in a day.

Twenty eight out of 29 youths attend school/colleges. As Table 2 shows, 7-8 hours are spent at school. While they do not help their mothers in cooking in monsoon and winter, 10 youths reported that they do so in summer This is perhaps because in summer their parents are busy in the fields and the children have holidays from school. Involvement in other domestic tasks was reported to varying extent Very few (1-4) youths reported that they collect fuelwood However, 5,6 and 12 youths (girls) reported that they collect fodder in monsoon, winter and summer respectively. Taking cattle out for grazing was reported by 15,2 and 17 youths in these seasons respectively. Nineteen youths reported that they help their parents in agricultural activities in summer, in a limited manner Clearly, youths do participate in agricultural activities. But during this period they mainly take over certain tasks that their parents would otherwise perform

For females, seasonal differences seem significant for time spent in agricultural activities and fuelwood collection. The differences are not significant for time spent in fodder collection and domestic activities. Seasonal differences in leisure time are also important, with the maximum reported in winter and the least in summer. For males, seasonal differences are apparent only in the time spent in agricultural activities and attending to cattle while they graze.

No significant differences were observed in time spent in any of the activities owing to differences in the altitude of the 3 villages, for all population groups This may be explained by two factors. (a) estimates from recall surveys are not accurate enough to observe significant differences, and (b) the difference in altitude of the three villages was not large enough to ensure that geographical and climatic differences significantly alter time allocation patterns.

Time Spent in various Micro-Environments: Table 3 summarizes the data on the time spent in a day in six micro-environments Adult females spend 60, 64 and 51% of their time indoors during monsoon, winter and summer respectively. The corresponding estimates for adult males are. 43,48 and 34 % respectively Youths spend 48,49 and 43% of their time indoors, in monsoon, winter and summer respectively. Children spend 67% of their time indoors in all seasons.

Time spent in cooking, as measured: In each selected household we measured time spent in cooking using a stopwatch. This measurement was made for each meal in a day in all three seasons. The average time spent in cooking in a day was 3.1 hours (n = 36). The standard deviation was 1 hour. The mean time spent in cooking a meal was to be 66 minutes. The seasonal means are 64,74 and 60 minutes in monsoon, winter and summer, respectively. The mean time spent in cooking a meal is the same for meals cooked in the morning and evening, i.e., 70 minutes Meals prepared at mid day have a mean cooking time of 55 minutes. Analysis of variance showed that very strangely, neither season nor the time of day have a significant effect on the time spent in cooking a meal. This is contrary to our intuition that cooking would last longer in colder seasons. Also, since different types of meals are cooked at different times of the day, this also would lead to significantly different means We are unable to explain the observed results and only further measurements would help clarify the matter. Cooking time was found to vary significantly with altitude. But here again our findings are unusual. Cooking done in villages at lower attitudes lasted longer than in kitchens at higher attitudes It was expected that at higher altitudes the lower temperature and atmospheric pressure would cause the duration of cooking sessions to be longer.

Measuring time spent in cooking using a watch yields accurate estimates. The only uncertainty associated with this measurement was that the presence of the investigation might have altered normal practices of the cook. But the effect of this was expected to be the same in al! instances. We can compare the time spent in cooking as measured with the estimates obtained from the questionnaire based survey. Females overestimated the time they spent in cooking by an average factor of 1.7. This factor ranged from 0.79 to 3.85. However, no correlation was observed between estimates obtained from these two methods. This suggests that erroneous estimates from the surveys are not systematic.

Fuel usage patterns

Type of fuel used: As mentioned earlier, woody biomass is the primary fuel used in this region. Crop residues and animal dung are rarely used for cooking. In the village Kweerali (914 m), 'Chir' Pine (*Pinus roxburghii*) was used in 37% of the cooking sessions and 'Tunga' (*Rhus parviflora*) was used in 21%. A shrub, Lanterna (*Lanterna Camara*), was used in 12% of the cooking sessions. In the village Kadola (1372 m), 'Tunga' was predominantly used (46%); while 'Chir' Pine was used in only 11% of the cooking sessions. In Bhainswara (1829 m), 'Chir' Pine is the most commonly used fuel (48%); followed by 'Banj' Oak (*Quercus leucotricophora*)

(21%). Thus it would appear that the tree species 'Chir' and the shrub species 'Tunga' are commonly used in this region.

A single species was used in 43% of the cooking sessions; while a mix of two species was used in 33%.

Moisture content of the fuel: Moisture content of the fuel (%) was measured using an electrical conductivity meter that had been calibrated appropriately. If a mix of more than one type of fuel was used for cooking then the mass weighted average moisture content was computed. Mean moisture content was 12% (range: 7-34, n = 96). Analysis of variance showed that season has a significant ($P < 0.005$) effect on moisture content of fuel. The monsoon, winter and the summer means were 14, 13 and 9% respectively. In this region the gathering and storing of fuelwood begins just after monsoon and continues during the winter months. In summer, the agricultural activities prevent collection of fuelwood. This may explain the discussed seasonal effects.

The average moisture content for 'Tunga', 'Chir' and 'Banj' is 14%, 10% and 11% respectively.

Fuel consumption per capita: The mean of the amount of fuel consumed per capita per meal was found to be 0.30 (range. 0.06 to 0 85, n = 96) kg. Variations due to time of the day factor were insignificant. It was expected that amount of fuel consumed would vary depending on the type of food being cooked. Since only one type of food is cooked in a meal; it was expected that the differences in means at different times of the day would be significant. The results of this study do not support this hypothesis in this region.

Variations in the per capita fuel consumption due to differences between households were between 14 and 25% of the total variation.

Seasonal variations were significant ($P < 0.05$). The seasonal means are 0 33, 0.32 and 0.25 kg for monsoon, winter and summer respectively.

Fuel consumption is least for families with 6-8 members. Beyond this size, fuel consumption increases However, because of the few samples of large families, these observations are not conclusive.

Fuel burnrate. The mean fuel burnrate was 1.49 (range. 0.32 to 4.85, n = 96) kg h^{-1}. Variations due to season and time of day were insignificant. Variations due to differences between households contributed only 5- 19% of the total variation.

Discussion

Our results confirm that, like in other rural areas, females work longer hours than men. However, time spent in fuel collection by females in this region far exceeds that in other parts of India and in Nepal (Reddy et al, 1980, Acharya and Bennett, 1981). This may be attributed to the rapidly shrinking forest cover, whatever its cause may be. We also observed that in this region collection of fuelwood and fodder are activities that are performed exclusive of any other activity and of each other. That is, other chores are rarely combined with these tasks, even during agricultural seasons. Exceptions may occur during crop harvest time. This observation contrasts with what was observed in other areas (Tinker, 1990). It is likely that females of this region may perceive time saving in fuel collection as a benefit, while this may not be so in other regions. Fetching water is not as time consuming as reported in other areas. The villages we studied have tanks and natural springs in their vicinity.

The time spent in cooking, as reported by females in our survey is comparable to that reported by other studies (Agrawal 1981, Smith et *al* 1983, Reddy et *al* 1980). However, females generally overestimated the time they spend in this activity - a serious drawback of the recall survey method The lack of a systematic pattern in such overestimation makes it difficult to recommend a uniform correction factor.

Youths of this region attend school and college and this activity accounts for most of their time During vacations and in the agricultural season, girls may assist their mothers in cooking, while boys take the cattle out for grazing. Girls help in fetching water throughout the year. Ives and Messerli (1989) have suggested that unemployment in adult males and youths, and the need to maintain even non-milking cattle for their meagre dung output may explain the long hours spent in attending to grazing cattle. Results of our study seem to confirm this observation.

Women and children of this region are the only groups that stay indoors longer than they stay outdoors. But even for these two groups the time spent indoors is significantly less than the time spent indoors by their counterparts in more developed societies. In an agricultural society, such as the one that has been studied, such patterns are to be expected. But the use of biomass fuels consisting of mix of species would require more indepth studies to understand their role in the energy and environment systems and health status of women and children in the region.

Responses to the time budget survey were highly uniform across individuals of a group. Whether the time-activity patterns are in fact uniform, or whether it is only the response to the survey questionnaire that is uniform, remains uncertain. A more detailed study for comparison of methods would be needed to resolve this.

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Table 1. Time allocated to various tasks by females and males (h)

Task	Females			Males		
	M	W	S	M	W	S
Agriculture						
Fields	0	4.0	5.1	1.0	1.4	6.6
Kitchen garden	-	-	1.3	-	1.0	2.4
Fuel/fodder						
Collecting wood	3 3	2.3	0 5	-	-	-
Collecting fodder	3.1	2.3	3 9	-	-	-
Collecting dung	-	-	-	-	-	-
Attending grazing cattle	-	-	-	5.2	5.8	4.6
Domestic						
Cooking	4.4	5.1	4.0			
Preparing tea	0.6	0.6	0.5			
Washing vessels	0.7	1.0	1.2			
Washing clothes	0.7	0 6	0.7			
Cleaning house	0.5	0.5	0.6			
Milking cow	0 6	0.5	0.5			
Cleaning cow-shed	0 5	0.5	0.5			
Fetching water	0.5	0.5	0.5			
Caring for children	1.8	2.4	1 0			
Employment	-	-	-			
Travel to work	-	-	-	1.1	1.3	1.1
At work	-	-	-	6.7	7.3	6.8
Leisure (+Market)	5.2	6.3	2.4	10.2	8.4	7.6
Sleep	7.1	7.7	6.5	7.6	8.3	7.0
Other	2.0	4.5	13.5	1.6		

M - Monsoon, W - Winter, S - Summer

Note: Each number in this table is an average taken over only those individuals who reported involvement in the task.

Table 2. Time allocated to various tasks by youth and childen (h)

	Youth			Children		
	M	W	S	M	W	S
Agriculture						
Fields	1.5	-	5.3			
Kitchen garden	3.0	-	4.5			
Fuel/fodder						
Collecting wood	0.5	2.5	-			
Collecting fodder	1.0	1 2	1.7			
Collecting dung	2.3	-	-			
Attending grazing cattle	3.3	4 0	5 4			
Domestic						
Cooking	1.5	2.0	1.1			
Preparing tea	0.5	0 5	0 5			
Washing vessels	0.5	1 5	0 6			
Washing clothes	0.5	1.0	1.0			
Cleaning house	0.5	0.5	0 5			
Milking cow	-	-	-			
Cleaning cow-shed	0 5	-	0 5			
Fetching water	0.5	0.5	0 5			
Caring for children	-					
Leisure (+Market)	7 9	6.4	12 3	3 6	12.0	4.7
Sleep	8 7	9.2	7.9	9.6	10.0	10.0
School	7.0	7 8	7 0			
Travel to school	1.0	1 0	1 0			
At school	6 0	6.8	6 0			
Play				9.1	-	9.0
With mother in kitchen				1.8	2.0	1.3
Other	2 4					

M - Monsoon, W - Winter, S - Summer

Note: Each number in this table is an average taken over only those individuals who reported involvement in the task.

Table 3. Time spent in various micro-environments (h)

Group	Season	Microenvironment 1	2	3	4	5	6
Children							
	M	1.2	0.6	14 0	1.0	4.6	2.7
	W	1.0	1.0	14.0	4.0	4.0	0.0
	S	1.1	0.3	14.7	1.3	4.0	2.7
Females							
	M	4.3	0.8	9 3	0.4	6.0	3.1
	W	5.2	1.0	9.2	1.1	3.2	4.4
	S	3 2	1.3	7.7	0 0	3.9	7.9
Males							
	M	0 4	0.0	10.0	1.7	2.9	9.0
	W	0.3	0.0	11.1	1.4	2.0	9.2
	S	0.0	0.0	8 2	0.2	2.1	13.5
Youths							
	M	0.4	2.2	8.8	1.8	2.1	8.7
	W	0.1	0.0	11.6	1.7	2.2	8.4
	S	0.3	0.2	9.7	1.3	2.9	9.7

M - Monsoon, W - Winter, S - Summer

1 - Kitchen during cooking sessions
2 - Kitchen during non-cooking sessions
3 - Living room
4 - Outdoors in the village during cooking sessions
5 - Outdoors in the village during non-cooking sessions
6 - Outdoors, far from village

List of tables

Technology Upgradation in the Energy Sector

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Technological Change in the Energy Sector

Introduction

The energy sector is a key sector in the Indian economy; its rapid development being pre-requisite for the sustained and rapid growth of the economy. Consequently, over the years allocations to the energy sector have tended to dominate the plan outlays of the Government of India. Table 1 provides in the allocations to the coal, electricity and petroleum sectors over the years, as well as the percentage of the total plan expenditure that these three energy sectors represent. Despite these heavy investments, energy shortages have continued to grow. The shortages are best documented in the electricity and the petroleum sectors, and indicate that the demand-supply gap seems to grow with growing investment in the sector Consequently, it is essential to look into the performance of the energy sectors so as to obtain an understanding of the productivity within each sub-sector.

Table 1: Investment in the Energy Sector

Period	Coal	Electricity	Petroleum	Total	% of Plan
Sixth Plan (1980-85)	3807.5	18298.6	8482.1	30,588.2	28 0
Seventh Plan (1985-90)	7122 3	37895.3	16008.8		27.9
Annual Plan (1990-91)	2391.8	11334 4	4130.1		29.1
Annual Plan (1991-92)	1863 0	12758.6	4057.4		28.4
Annual Plan (1992-93)	2405.0	14943.9	6054.0		28.9

Source [1]

In order to assess sub-sectoral performance, it is important to identify an index that is both economically significant as well as useful from a policy strategy perspective. Total factor productivity (TFP) is used as such an index here: it measures changes in output per unit of all inputs combined. Generally speaking, there are two major inputs into all the energy sub-sectors - these are capital and labour.

To illustrate the usefulness of TFP, consider the case of the coal sector in the 13 years between 1974-75 and 1987-88. The value added by the sub sector increased at about 7.7% per year. Its capital stock grew at 7.9% per year during the same period, whereas the labour input decreased at about 0 85% per year. In the capital-labour mix in the coal sector, capital accounted for about 84% and labour, 16% Consequently, inputs were and rising at 6.5% per year: 0.84 times 7.9% (for capital) plus 0.16 times -0 85% (for labour). Total factor productivity, or the residual thus accounted for 1.2% in output growth: 7.7% (the growth rate of output) minus 6.5% (the growth rate of inputs)

What makes up the residual or the TFP? Conventional wisdom indicates that there are two major reasons· technological innovation, and the quality of labour. If the additions to the labour force are more productive than the existing force, they will add more to output than that predicted by the formula based on labour share,and the extra contribution from upgrading the quality of labour ends up in the TFP

Technological innovations include both large scale changes in the technological process, as well as numerous ways of reducing costs in existing technologies. Large scale upgradation of technological processes is, to a major extent dependent on the scale of production; the greater the level of economic and physical activity, the greater is the scope for introducing the new technologies. Enhancing labour productivity and exploiting incremental technological change, however are largely dependent on the work environment created within an enterprise.

In a recent analysis of productivity in the public sector Anita Kumari [2] has analyzed productivity trends for 11 groups of manufacturing industries in the public sectors These include the three major energy sub-sectors, viz. coal, electricity and petroleum. Figure 1 shows the variation in TFP over the years analyzed in the study In all cases, the base year TFP is taken as 100 In the coal and petroleum sectors, productivity increases have been marginal (less than 4% per year), though the value added by these sectors grew at more than 10% per year during the period of the study In the electricity sector, the productivity rise has been spectacular; increasing from 100 in 1982-83 to over 500 in 1985-86 and declining to about 400 in 1987-88 The study also investigated the increase in TFP on the growth in scale of production and on "labour management relations" In all the three sectors,growth in scale of production have been generating total factor productivity, but "labour management relations" were found to result in deteriorating total factor productivity.

In the next section, we present a historical evaluation of the technological change experience in India from the perspective of assessing the environment within which this change has occurred, and therefore assess the conditions which would be required so that enterprises continually "invest" in productivity-increasing technological change

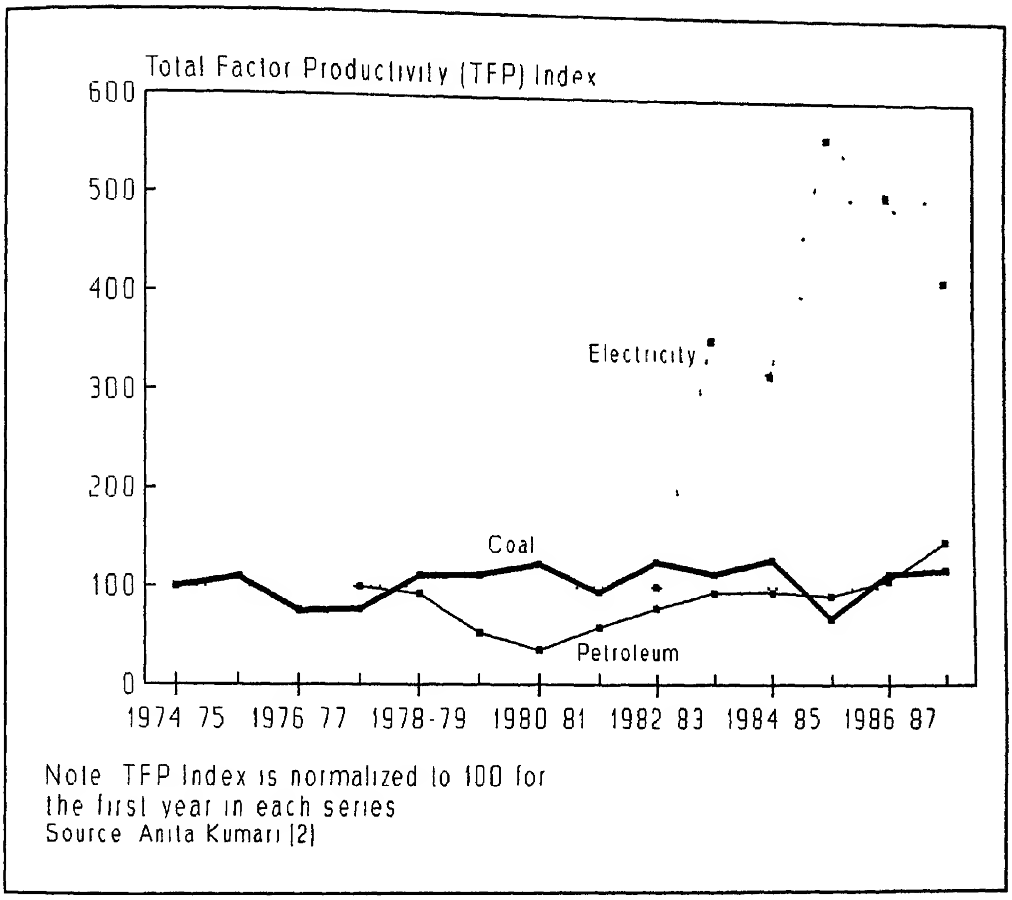

Figure 1 Variation of the total factor productivity index in the energy sectors

Technological Change in India: An Evaluation

The achievements of technological effort by the leading enterprises in the Indian energy sector are impressive. Their technological capabilities extent over a broad range of the relevant aspects of technological activity, and for each of these aspects, they reveal considerable depth of learning. Over much of this range of industries, India can identify, design, engineer and manufacture the bulk of capital goods for a new project. It can select and implement new foreign technologies, adapt them to local materials and market needs, and improve upon them over time. It can develop and introduce some new products and processes. It can organize and coordinate large, complex manufacturing processes. It can set up supplier networks, with all the technology transfer, quality control and logistical efforts this entails. It can also transfer technology to customers and manufacturers in similar activities, in the form of licensing, turnkey plants, joint ventures or technical assistance This set of diverse and deep capabilities places India among the leaders of the developing economies which have exported their technologies in international markets [3].

The failures are also impressive. Evidently, substantial resources were invested in technological infrastructure with very little benefit to the long-term quality or quantity of technology in use in organized industry. Even among the better manufacturing enterprises, the focus of this study, there are failures of several sorts. A lot of technological effort went into coping with problems generated by the import-substituting regime. Some of this effort was undoubtedly valuable; it brought new local materials into use and provided a base of process engineering know-how which could be deployed under any trade regime. Some, however, was wasteful, and could prove to be unnecessary and worthless in a more outward-oriented regime

In the coal mining sector, for example, longwall mining technology for underground mining was imported from the U K in the seventies. Underground mining productivity in India was less than 0.5 tonnes per manshift at that time (prior to imports); on the other hand, mechanised longwall faces produced over 15 tonnes of coal per manshift in the U.K. India imported equipment for seven faces and then tried to indegenize the equipment. Presently (nearly twenty years later), the total number of mechanized longwall faces in India are just eight, and productivity is 9 tonnes per manshift A contrary example is that of China which also decided to import the same technology at the same time. However, they imported over a hundred faces in the first instance. Today, there are over 650 faces in operation in China, with a productivity of about 15 tonnes per manshift [4]. The difference in the two experiences lies in the scale and target of technological change India imported a few units and has been trying to indegenize the engineering The small quantity of sales has not spurred the UK company to help in indegenization and adaptation On the other hand, the Chinese first learnt how to use the equipment - the UK vendor was actively involved in the adaptation and training process. The local manufacture in China started after the initial operational learning phase was over providing feedback about the local technological requirements and therefore facilitating a deeper and more productive transfer of technology

At the same time, the fiscal and economic regime in India created disincentives to effort to constantly upgrade technologies in line with international standards Worse still, it often detracted from engineering and managerial efforts to implement even existing knowledge with the level of efficiency which other developing countries achieved a continuing waste of resources for the country Artificial constraints held back growth and technological competition within India; the generally sluggish industrial growth created by the government's policies held back both the pace of learning and its deployment, and the anti-export bias and infrastructural constraints held back the exploitation of Technological Change for foreign markets.

The insipid performance in the energy sectors must be set against the fact that all are, or have been competitive in world markets Yet they have either lost established markets abroad or failed to achieve export take-off, at a period when other developing countries, with apparently lower technological endowments (and higher labour costs), have made major inroads into world markets. Like India, the other newly industrializing developing countries also did not make major innovations in product or process technology Unlike India, they were able to efficiently assimilate and implement in production a constant stream of new technologies copied or bought from abroad. Both invested heavily in

technological change, but the direction of the effort differed, as did the environment which encouraged or inhibited the exploitation of technological change.

It is possible that the difference in performance in similar industries between India and, say, South Korea was partly traceable to cultural and sociological factors. Perhaps economists attribute too much to purely economic factors in determining efficiency and dynamism in industrial activity. In the final analysis, though, it does appear to the economist that an overwhelming portion of the blame for the failures of technologies effort in India was economic· and can be traced directly or indirectly to economic policies pursued by the government Some of its achievements have also resulted from these policies It is likely, however, that these achievements would have been more weighty and socially beneficial had a different set of policies permitted the same talents to be deployed.

In the past three years, the economic and fiscal regime has changed dramatically. Technological competition is spurred through liberalized trade and lower tariffs, and at the same time, increasing energy prices (to levels where they reflect costs) provide the financial soundness necessary to invest in technological change. In order to effectively manage (and generate) technological change, it is essential to identify and develop the capabilities that allow energy enterprises to consciously sustain productivity enhancement in a competitive environment.

In the remainder of this paper, the nature of these capabilities is analyzed, and then policies and strategies to promote their development are highlighted.

Capabilities to Generate and Manage Technological Change

Two issues have to be considered while studying the nature of this capability. The first is the ability to exploit a technology efficiently, as well as innovate to enhance its performance. The second is the ability to respond effectively and rapidly to economic signals in the market so as to maintain (and enhance) efficiencies of labour productivity, energy use, and capital utilization through the innovation/adaptation of existing technologies or the acquisition of new technologies

What does it take to achieve this capability? In the highly regulated electricity industry in India, two companies have consistently maintained operating efficiencies far in excess of the national average, demonstrating a capability to rapidly absorb new technology and often operate it with efficiencies higher than they were designed for. Also, in response to changes in the quality of coal and lignite supplied to them, they have successfully carried out technological modifications that enable them to handle inferior-quality fuel [5,6]

In both the companies, the prime reason for the success seems to be their conscious development of a group of professionals who continuously interact with both technology vendors and plant operators. They also follow technological development in the

electricity industry, and have over a period of time, acquired the ability to understand what it takes for the technology to operate at its most efficient level, and to engineer cost-effective measures to maintain plant efficiency in the face of changing conditions Their cumulative experience has also been fed forward to improve the engineering of new projects and the quality of recent technology purchases.

These groups are the link between two important processes in the market: the production of goods, and the development of technology for that production.

The surprising fact is that though the need for developing these "human-endowed technological capabilities" [7] is seemingly self-evident, they are highlighted in this country only because of their rarity. The reason is largely economic· these capabilities need a long time (on a business timescale) to show results, and require highly-talented professionals [8]. Both these translate to additional costs And in an economic environment where change has been slow and regulated, there was no incentive to invest in these capabilities which, in turn, lead to decline in long-term performance [9,10].

The conscious development of this capability has been keystone of rapid economic development in the newly-industrialized countries In Korea, the national electric utility's economic and technical performance improved steadily though the past two decades, and today compares favourably with that in the industrialized countries [11]. Behind this trend lies a record of constant learning and training so as to strengthen its technical, managerial, and engineering skills. This involved a variety of efforts that included an emphasis on the learning and understanding of technology equal to that on the acquisition of goods and services, training of large numbers of engineers and operators in overseas plants and engineering design organizations, and internal procedures (including financial incentives) to reinforce learning through interaction of experience and training. The managerial and technical capabilities that were developed have also seeded other internationally-competitive technology-based firms that were later established in Korea

Strategies to Sustain Technological Change

Any initiative seeking to encourage technological change would have to incorporate the development of change-managing capabilities that encourage the enhancement and sustenance of technological development in firms The development of these capabilities requires, first and foremost, corporate commitment However, in the currently liberalizing economy where, till recently, the development of these capabilities could have been a liability, and where the emerging market, as yet, does not actively necessitate their existence, macroeconomic policies are required to stimulate their expeditious development. Five elements of a proactive national strategy are outlined in the following

Opportunity Costs of Capability Development

The first strategy would involve the incorporation of the costs associated with capability development in the overall financial framework of the firm. This implies, first, an acceptance that the absence of human-endowed technological capabilities represents lost opportunities Second, an assessment of these lost opportunities is required. Such an assessment could be based on a comparison of performances of firms with and without this capability The goal would be to understand, in economic terms, the opportunity cost of developing this capability, and hence the investment justified in its development. Alternate project evaluation procedures incorporating this human-capital worth should be increasingly required by governments, financial institutions, and multilateral agencies such as the World Bank

The opportunity cost of capability development in the energy utilization technology industry (e.g , refrigerators, washing machines, electric lamps, space conditioning etc.) has been internalized in Sweden in an innovative manner[12] The Government brought together technology purchaser groups (e.g., managers of housing complexes) who assured the purchase of a large order if the technology offered was much more energy-efficient than the currently available technology The level of energy-efficiency increase required was calculated on the basis of short payback periods which would make the new products attractive enough to replace the current stock. For example, in the case of electric lamps, a firm order of 26,000 lamps was guaranteed to a company that supplied a lamp that was 25% more efficient than the currently available lamps. Three companies participated in the programme; the winning lamp was over 30% more energy-efficient However, because of the technological change internalized in the three companies during the competition, open market sales also increased dramatically. about 65,000 were sold in the first year, and about 140,000 in the second year. At the same time, the price was reduced to almost half of the initial price. Consequently, the costs of capability development within the companies were adequately recovered from enhanced sales

Financial Incentives

The second element of a national strategy should aim at encouraging firms to develop capabilities to manage change by providing them opportunities to expand into new markets. A possible configuration to achieve this goal could be the establishment of venture capital funds to finance projects that involve some inhouse engineering before commercial production can commence. India has only two organizations that provide venture capital for technological development; most bankers are not comfortable with risk-based lending that involves pre-commercial development as well. Three years ago, the U.S Agency for International Development established a program along these lines in India. Called PACER (Program for the Acceleration of Commercial Energy Research), it is managed by an ICICI, and provides loans to firms on a profit- (or loss-) sharing basis for the commercial production of energy-efficient technologies. The projects necessarily have to involve some technological development activity. It is too early to evaluate the role of PACER in human-endowed technological capability development in the Indian

market; anecdotal evidence suggests a positive correlation in the vast majority of the firms involved in the Program.

Scope and Depth of Technology Transfer

The third strategy would be to deepen the content of technology transfer. It is important to note this converts a one-step transfer into a long term process. Typically, the transfers do provide for some training, but the depth and scope of technology transfer would have to be enhanced if indigenous capabilities are to be developed. Longer linkages; involvement of the recipient firms in problem-solving associated with the technology elsewhere in the world; and in technology modification, and possibly their involvement in future technological development, would improve capability building in India This complicates the direct connection between financial transfers and the provision of goods and services, but could still be handled in a financially accountable manner by the incorporation of assessments suggested in the first strategy. The mechanisms could be managed in a manner similar to the technical assistance program of the United National Development Program (UNDP). A necessary corollary of this process is that relationships between transnational and their licensees in the marketising economies would need to be reevaluated. It might be beneficial to both parties to invest in joint ventures rather than outright technology licensing.

Energy Efficiency Standards

The development of a process of evolutionary standards is the fourth strategy to encourage the development of human-endowed technological capabilities to manage change. Product performance and safety standards are necessary to ensure that products can enter the international market However, in many instances, it may not be possible to impose a one-step change from existing practices to international standards, the governments may then adopt an evolving set of standards that encourages the development of this capability as the most cost-effective means to maintain compliance with standards Escalating efficiency standards imposed by government on U S appliance manufacturers required firms to innovate or exit In the process, surviving companies developed engineering expertise which has been repeatedly called upon to meet new technical challenges, including finding alternatives to CFCs while simultaneously ensuring compliance with tougher energy standards for refrigerators [13] While this non-market-driven technology-forcing has been costly, it has resulted in refrigerators which use 55% less energy than in 1972, and is possibly one of the reasons why Japanese refrigerators have not displaced American refrigerators in the U.S. market.

Education and Training

Finally, the governments will have to recast their education systems There is a need to provide advanced and applied technological and managerial training to people in whom the capabilities to manage technological change are to be endowed. To a certain extent,

the Soviet model with its applied technological institutions is desirable. However, their focus would have to widen from technological development alone to technological change. Also, as skills to manage change are acquired cumulatively, they are not easily communicated through traditional pedagogy Short-term advanced courses for working professionals would need to be designed and established. The industrialized countries have institutionalized this process through courses organized by professional organizations, training institutes, etc Their experience may be utilized to establish similar structures here. The content of these courses would, however, be best culled from experiences in India itself, or from those in the recently marketised economies.

In this section, we have outlined broad national policies and strategies that would sustain productivity-enhancing technology change in the energy (as well as other industrial) sector In the last section of the paper, we focus on the targets of such policy, and identify the types of enterprises that are critical to the process, and their role in promoting technological change

Capacity Building: The Operational Focus

Capacity building has to reflect a greater understanding of linkages in, and environmental impacts of, decision making at various levels in the energy sector *Capacity building has largely to be aimed at enhancing human-endowed capabilities within firms to handle technological and trade-pattern changes in a manner that is both economically and environmentally sustainable* This capability is characterized by three major features: a) a reasonably long-term business horizon; b) awareness of the upstream and downstream linkages associated with the operation/decision that an individual is involved in; and c) awareness of, and relatively rapid access to information and analyses that are necessary in decision making

Business time horizons are largely dependant on the overall economic situation in the country, the fiscal policies of the government, and the structures of the capital market. The broad national strategies in these areas have been identified in the previous section.

The key issue in capacity building at the enterprise level is that the economic imperative of installed capacity expansion has resulted in effective delinking of decision-making in the energy companies from the resulting implications in both upstream and downstream industries and markets This leads to situations that are environmentally and/or conomically ridiculous The emphasis on electricity generation expansion as r ulted in massive environmental damage due to expansion of open-cast coal mining hich was necessitated by the need to rapidly enhance coal production), as well in onomic inefficiency due to the extremely inefficient use of electricity in nearly all plications, specially in the agricultural sector (largely because of electricity pricing does not reflect the true costs incurred in its generation and distribution).

Emphasis on downstream and upstream linkages can be enhanced through the consortia funding approach mentioned earlier, enhancing competition (so that no corporate entity can take input availability or product consumption for granted), and

mechanisms/regulations to ensure fair pricing and compliance with environmental regulation. These institutional linkages must be based, as far as possible, on the self-interest of the actors, rather than on monitoring and control. The environmental liability concept (in which all industries are required to purchase environmental insurance, and the insurance companies compensate those who are affected because of an industry's environmental impacts) is a good example of such a linkage, as opposed to the existing monitoring and regulation framework alone which promotes corruption and non-compliance.

Achieving longer-term business horizons and ensuring consideration of upstream and downstream linkages during decision-making in firms requires that the decision makers are aware of the consequences of their decisions; possess the tools to analyze information so as to make these decisions, and have access to the required information. In order to assess the training needs so as to develop this it is useful to identify who these decision makers are, and what type of decisions do they make. Broadly speaking, there are two types of decision makers those associated with corporate policy, and those associated with the operation of the energy companies whose decisions help in maintaining and increasing the efficiency of operations within the enterprise *The number of people covered by these definitions are obviously very large, there is, therefore, a need to create institutional configuration that promote capacity-building through formal training, as well as through routine professional interaction The key or linkpin organizations in this regard are financial institutions and consulting organizations They are relatively fewer in number and interact with large numbers of clients Their multiplier effect (of encouraging capacity building through professional interactions) is therefore large Professionals in these organizations should be statutorily required to undergo training that would enhance their capabilities in the perspective of sustainable and environmental development.*

In the case of consulting organizations, there would be a need to develop training programmes for specific sub-sectors, e.g for coal, petroleum, electricity, and so on The trainers for these linkpin organization-training programmes should have technic-l experience, as well as awareness of the larger economic and environmental linkage The development of these trainers should the prime responsibility of the governme A strategy that could be adopted would be to establish expert groups for each sect under consideration (with three to four members in each group) with the charter develop an effective syllabus for the development of trainers The training courses identified could be carried out through the existing research and training institutes in th country The trainers could then form independent training organizations, or becom part of existing research/training organizations, who would then offer the statutoril required training programmes for professionals working in the linkpin organizatio Professionals from other organizations (non-linkpin organizations) should also encouraged to attend these training programmes through incentives such as corpora tax-breaks, etc.

Conclusions

To summarize, capacity building for internalizing productivity-enhancing technological change practices in the energy sector in the country would require fiscal policies that promote competition, ensure fair pricing, encourage resource allocation linkages with efficiency norms, and a relatively diverse capital market Simultaneously, these should be complemented with enhancing the human- endowed capabilities in firms through the development of training programmes that enhance the capabilities of individuals in firms to make decisions that are economically and environmentally sustainable. For this purpose, the government should encourage establishment of a range of training programmes for individuals in business organizations, both at the policy and the implementation levels The policy level programmes would focus on creating the need to internalize long business time horizons and consideration of upstream and downstream linkages in business decisions The implementation level programmes would focus on need for the continuous enhancing of resource-use efficiency in the operation of the firms The training programmes would especially emphasize the training of professionals in linkpin organizations (financial institutions and consulting firms which have a multiplier-effect through professional contacts with a large number of clients) . These training programmes could be provided by a range of organizations where the trainers have themselves been trained at specialized programmes which have been developed at the national level.

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